2007 LONG TERM MONITORING

PACIFIC SOUND RESOURCES SUPERFUND SITE

SEATTLE, WASHINGTON

MONITORING REPORT

FINAL

AUGUST 1, 2008

Prepared for:

U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South
Seattle, Washington 98134

Prepared by:

Science Applications International Corporation
Environmental Sciences Division
18912 North Creek Parkway, Suite 101
Bothell, Washington 98011

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

List of Acronyms

AET	Apparent Effects Thresholds
CAS	Columbia Analytical Services
CSL	clean up screening levels
CTD	conductivity-temperature depth
DMMP	Dredged Material Management Program
GPS	global positioning system
MHHW	mean higher high water
MLLW	mean lower low water
MIG	mean individual growth rate
MLLW	mean lower low water
MSU	Marine Sediments Unit
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
OSA	outside the remediation areas
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PSEP	Puget Sound Estuary Program
PSR	Pacific Sound Resources
QAPP	Quality Assurance Project Plan
RA	remedial areas
ROD	Record of Decision
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SD	statistically different
SMS	Sediment Management Standards
SQS	Sediment Quality Standards
SVOC	semi-volatile organic compound
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1.0 Site Description and Background

The Pacific Sound Resources (PSR) Site (formerly known as the Wyckoff West Wood Treating Facility) is a Superfund Site, located along the southern shoreline of Elliott Bay, Seattle, WA (Figure 1-1). The site is divided into two remedial operable units: an Upland Unit and a Marine Sediments Unit (MSU). The current investigation described herein only addresses monitoring activities for the MSU.

A wood-treating facility operated at the site from 1909 to 1994. Sediments in the MSU were contaminated by discharge of waste creosote and other wood-treating chemicals. The primary chemicals of concern in the MSU include: polycyclic aromatic hydrocarbons (PAHs), phenolic compounds, dibenzofuran, polychlorinated dibenzodioxins and dibenzofurans (PCDD/F), polychlorinated biphenyls (PCBs), and mercury (USEPA 1998). The Record of Decision (ROD) identified the selected sediment capping and limited dredging as the remedy for the MSU (USEPA 1999). The extent of the capping was to address all areas with sediment contaminants exceeding the Washington State Sediment Management Standards (SMS) cleanup screening levels (CSL), and areas with PCBs exceeding the more conservative SMS sediment quality standards (SQS) criteria. The ROD requires that the capped area remain at or below the SQS for all contaminants (USACE 2004).

For engineering purposes, individual Remedial Areas (RA) were developed according to specific site conditions and operational considerations that require different cap designs, cap materials specifications, or construction methods. RAs 1 through 3 cap construction activities were conducted from August 2003 through February 2004, with a final inspection in April 2004. RA 4 cap construction was conducted in September and November of 2004, with a final inspection in November 2004. In RAs 1, 2b, and 4 the cap thickness was within the design criteria, design modifications reduced the cap thickness in RA2a, and the RA3 capping material prohibited through-cap core sampling (USACE 2005). Results for each RA are summarized in the Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) (SAIC 2007).

Cap construction activities were conducted in January and February 2005 for RA5 of the MSU. RA5 consists of the two sub-areas RA5a and RA5b, which are approximately 20 and 2 acres in size, respectively (Anchor 2005). The design specifications for the cap in RA5 was for a minimum thickness of 27 inches (24 inches following consolidation) of sandy dredged material. With a 13-inch operational allowance, the RA5 cap should range from 27 to 40 inches as placed (USACE 2004). Initial post-construction monitoring in RA5 found that the cap did not meet design thickness. Chemical and physical results from surface and subsurface samples are summarized in the SAP (SAIC 2007; USACE 2007).

This report provides the objectives (Section 2.0), methods (Section 3.0), and results (Section 4.0) for the data collection activities to support the 2007 Long Term Monitoring of the PSR Superfund Site. The data collection activities included the collection of surface and subsurface sediment, the chemical and toxicological analysis of surface sediments, the determination of the remedial cap thickness, bathymetric survey of the subtidal site, and a beach survey of the intertidal portion of the site. Section 5.0 provides a summary of the 2007 monitoring effort as well as recommendations for further monitoring. References are listed in Section 6.0. The appendices include the PSR Field Report (Appendix A), the PSR Chemical Data Final Report (Appendix B), the Analytical Laboratory Report (Appendix C), the Biological Laboratory Report (Appendix D), Bathymetric Survey Information (Appendix E), Beach Survey Images (Appendix F), and Subsurface Core Images (Appendix G).

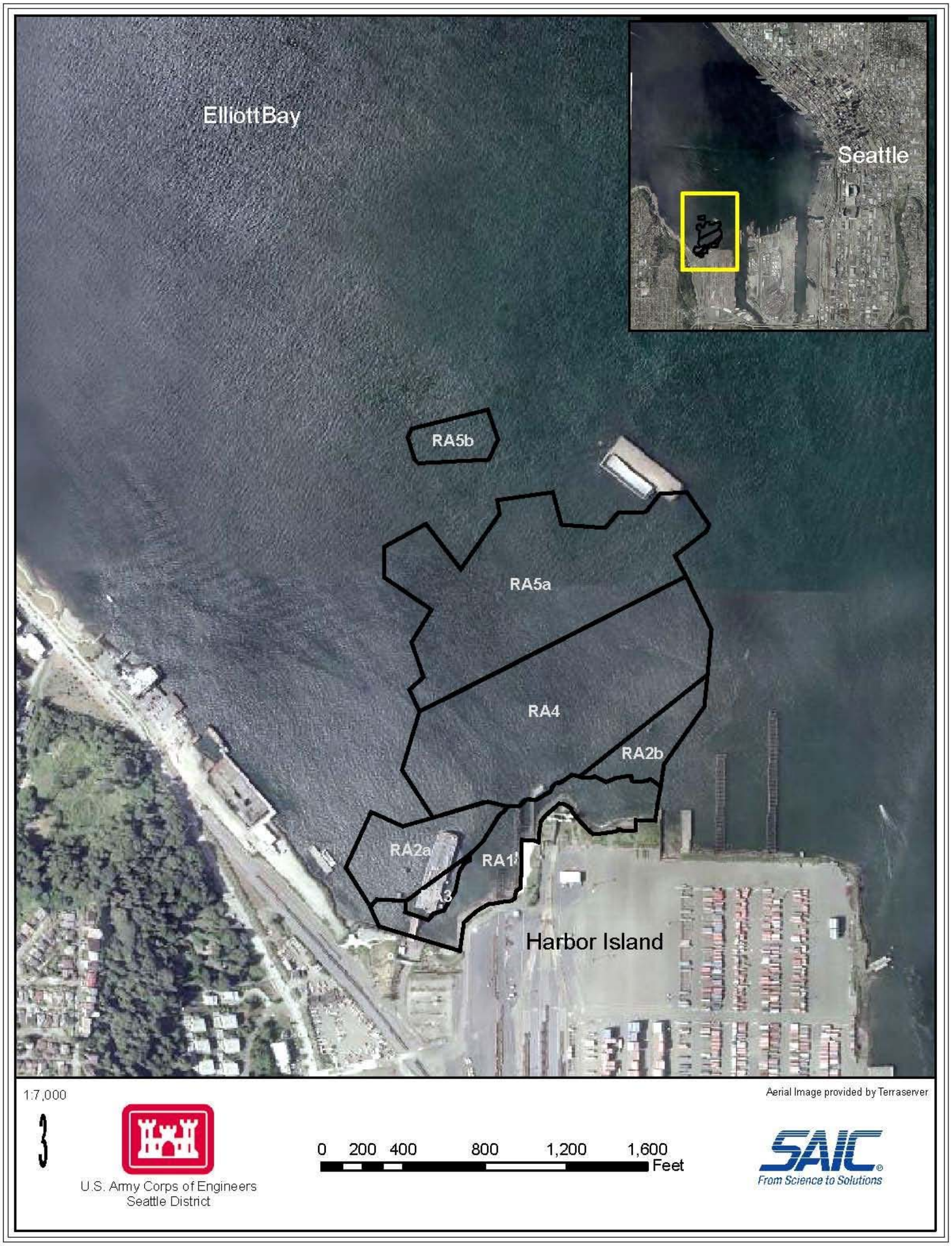


Figure 1–1. Elliott Bay Pacific Sound Resources (PSR) Site

2.0 Monitoring Objectives

The 2007 monitoring event provided field and technical support for long-term monitoring of the MSU of the PSR Superfund site (USACE 2007). The purpose of the investigation is to determine whether the current cap design continues to meet chemical criteria over time.

The long-term monitoring of the PSR sediment cap consists of three decision-making processes (physical, chemical/biological, and recontamination) that describe how the data collected during PSR monitoring are used. Each decision process is two-tiered, with the first tier addressing identification of cap effectiveness or ineffectiveness. The second tier ("expanded testing") addresses the cause(s) of ineffectiveness, if any, that are found in tier 1, and is intended to provide the Environmental Protection Agency and the State of Washington with information for augmenting or altering the remedy. Effectiveness will be based primarily on the ability of the cap to provide surface sediments in the biologically active zone of compliance (0 to 10 cm) at or below the SQS (USACE 2007).

One significant change from the initial monitoring program layout as described in the 2003 Operation, Maintenance, and Monitoring Plan is the inclusion of biological monitoring as a tier 1 method rather than as a tier 2 method (USACE 2004). Biological monitoring is intended to strengthen the weight of evidence approach used in this monitoring program to support state acceptance of the site (USACE 2007).

The overall post-construction monitoring objective is to determine whether the cap is an adequate and effective remedy. Specific long-term monitoring objectives for PSR are to: (1) determine physical stability of the completed sediment cap to ensure its ability to physically isolate contaminated sediments is not compromised, and (2) document surface sediment quality of the cap relative to the State of Washington SQS. Table 1-1 in the 2007 SAP (SAIC 2007) outlines the monitoring and evaluation methods for each monitoring objective (USACE 2004, 2007).

The 2007 monitoring event included the collection of 30 surface (0 to 10 cm) sediment samples and 16 subsurface samples. Twenty three of the surface samples were collected within the remediation areas (RA2B, RA4, and RA5). An additional seven samples were collected outside the remediation areas (OSA). All 16 subsurface samples were collected from RA5. Surface sediment samples were submitted for chemical and conventional analyses. The surface sediment chemistry results were compared to SMS SQS criteria to determine whether the cap material is in compliance with the PSR ROD (i.e., meets the SQS criteria) and to identify whether increases in contaminant concentrations have occurred (USACE 2007).

Through-cap subsurface cores were collected to determine cap thickness in RA5. Cores were photographed, measured, and documented. Samples of the cap material were archived for optional chemical analysis, contingent on whether co-located surface sediment contamination exceeds SQS criteria.

3.0 Data Collection and Analytical Methods

Field sample collection and analysis was conducted in accordance with the PSR SAP/QAPP (SAIC 2007). The field activities including the surface and subsurface sediment sampling, bathymetric surveys, and beach surveys were conducted from August 3 to August 16, 2007.

3.1 Sediment Sample Collection Methods

Surface sediment samples were collected using a Young grab sampler and a double van Veen grab sampler; subsurface sediments were collected using a vibracorer. All sediment sampling was conducted aboard the R/V *Kittiwake* owned and operated by Bio-Marine Enterprises. Surface sediment grabs were successfully collected at 23 locations located within the boundary of the PSR MSU (Figure 3-1) and seven locations outside the boundary of the cap area.

Subsurface sediment samples were successfully collected at 16 locations within the boundary of RA5 (Figure 3-2). The vibracorer had difficulty in penetrating overlying cap material at locations along the RA5/RA4 boundary and in the RA4 and RA2 zones. A minimum of three attempts were made before abandoning and/or re-locating a station. Four additional locations were added in the field in an attempt to obtain subsurface sediment cores. Upon retrieval of the vibracorer, 1- to 4-inch rocks lodged in the core tube and core catcher were observed at several locations. Two core catchers and a core tube were lost in attempts on August 14 and 15. On August 15, with only one core catcher remaining, subsurface sediment sampling was concluded due to the loss of the core tube and core catcher at station RA5-36. Due to the type of vibracore sampler and the water depth at the site, it was not possible to accurately determine the actual penetration depth. Therefore, the percent sediment recovery could not be calculated.

Surface sediment samples were submitted for chemical analysis, whereas subsurface sediment (i.e., through-cap cores) were processed and archived but not submitted for chemical analysis. A more detailed discussion of the field sampling effort is provided in Appendix A: *2007 Long Term Monitoring Pacific Sound Resources Superfund Site, Seattle, Washington, Field Report*. Photographs taken of the subsurface sediment cores during processing are provided in Appendix G.

3.2 Analytical Methods

Chemical analyses were conducted by Columbia Analytical Services, Inc. (CAS) of Kelso, WA. The analysis for semi-volatile organic compounds (SVOCs) and PCBs were carried out by methods 8270 and 8082, respectively. The analysis for most of the metals was carried out using method 6020, while mercury was analyzed using method 7041. Sediment conventional parameters, including grain size, total organic carbon (TOC), and total solids, were analyzed using methods Plumb, Puget Sound Estuary Program (PSEP), and 9060, respectively. The specific analyses and conventional parameters measured, sediment, analytical methods, and target detection limits are provided in the SAP (SAIC 2007). A summary of the data results and quality assurance/ quality control review are provided in Section 4.1 and the Chemical Data Final Report (Appendix B).

3.3 Biological Testing Methods

Confirmatory biological testing was performed on the 23 surface sediment samples collected from the PSR RAs. Samples collected from outside the cap area were not submitted for biological testing. The confirmatory biological testing program consisted of three toxicity tests including amphipod mortality, larval development, and juvenile polychaete growth bioassays. All biological testing was conducted in compliance with the Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments (PSEP 1995) with appropriate modifications as specified by the Dredged Material Management Program (DMMP) agencies in the annual review process. One exception occurred with the collection of representative reference sediments for use in the interpretation of bioassay test results (Section 4.3.2). The general biological testing procedures are discussed in greater detail in the SAP/QAPP (SAIC 2007).

The three bioassays were conducted on a total of 26 sediment samples including three reference sediments. All biological testing was conducted by Nautilus Environmental of Tacoma, WA. Surface sediment samples were submitted directly to the biological laboratory for testing. The three reference sediment samples were collected from Carr Inlet and are used for evaluating the test results relative to the Washington State Sediment Management Standards biological effects criteria (Ecology 2003). The biological testing results are summarized in Section 4.3. The biological laboratory report is provided in Appendix D.

3.4 Bathymetric Survey Methods

The survey design for PSR was created in HYPACK® Max survey data acquisition software with individual single-beam survey lines established over a 2,750- by 3,000-foot base survey area. A total of 56 planned, main scheme bathymetric survey lines were established at 50-foot intervals, subdivided into primary and secondary areas of importance. The lines were oriented in a north-south direction to optimize detail on water depths and seafloor topography, minimizing the occurrence of slope-induced survey artifacts on subsequent depth difference comparisons (Figure 3-3). The survey area was prioritized to obtain the data most important to depth difference comparisons and determination of cap stability/status. Secondary areas were occupied as time and weather conditions within Elliott Bay permitted. Included in these secondary lanes were a series of cross lines, which verified the accuracy and reliability of surveyed depths and plotted locations. Additional details on the specific methodology for the bathymetric survey are provided in the SAP/QAPP (SAIC 2007).

3.4.1 Geodetic Parameters

Geodetic parameters for measurements in the horizontal plane were based in Washington State Plane Coordinates (WA-4601 North) system and referenced to the horizontal control of the North American Datum 1983 (NAD 83). A common vertical datum of mean lower low water (MLLW) was used as the basis of all depth and elevation measurements obtained as part of this monitoring survey.

3.4.2 *Equipment*

Bathymetric survey data were collected using an integrated data collection system installed aboard Science Applications International Corporation's (SAIC) 20-foot aluminum survey vessel. The sampling equipment included as Odom Hydrotrac® survey echosounder was utilized in conjunction with a single, narrow-beam acoustic transducer, HYPACK® Max bathymetric data acquisition software, an RTK global positioning system (GPS) antenna mounted directly above the transducer, a Trimble R7 base station, and a Trimble R8 receiver.

Prior to conducting the bathymetric survey, the Trimble R7 base station was established over the known National Geodetic Survey (NGS)/National Oceanic and Atmospheric Administration (NOAA) tidal benchmark (NGS Station PID# SY0290) to ensure proper operation and to transfer first order control in the horizontal and vertical planes to a point located within the worksite. This benchmark was located in downtown Seattle along the waterfront and within the footprint of a Seattle fire station on Alaskan Way (Appendix E).

To establish the reference point within the PSR worksite, the Trimble R7 base station was mobilized over the NGS benchmark location, while the Trimble R8 receiver was situated at a fixed location at the PSR survey site. The benchmark position and elevation, and the height of the GPS antenna, were input into the Trimble R7 base station and used to calculate the horizontal and vertical offset between the precisely known height and position of the benchmark to position and height calculated based on satellite data. The difference measurement within the Trimble R7 base was then used to develop a real-time corrector that was transmitted to the Trimble R8 rover within PSR via a Trimble TrimTALK VHF radio. The Trimble R8 rover was held static on a pier within PSR for approximately one hour, obtaining both data from the GPS satellites and correctors via the radio. After "burning-in" for one hour, the position and height resolved by the Trimble R8 rover was then deemed sufficiently accurate to use as both the horizontal and vertical control reference point for the PSR survey activity.

During actual survey operations, the Trimble R7 base station was placed at the reference point established within the PSR worksite. The confirmed position and elevation of the PSR reference point and the height of the GPS antenna over that point were input into the Trimble R7 base station. The Trimble R7 unit then calculated the horizontal and vertical offset between the data from the GPS satellite data and the reference point, and then transmitted the correctors via a VHF radio link to the roving Trimble R8 receiver mounted over the bathymetric transducer aboard the survey vessel. The corrections were then applied to the GPS satellite data in real time, such that the roving R8 receiver provided three-dimensional GPS positioning data at centimeter-level accuracy to HYPACK® Max (Equipment configurations and settings are included in Appendix E).

3.4.3 *Vertical and Horizontal Control*

The Odom Hydrotrac® echosounder and RTK GPS positioning systems were checked and calibrated as necessary at regular intervals prior to and during the survey operations. The transducer was mounted 1 meter below the still water surface and routinely monitored throughout the survey. Initial bar checks were conducted at the beginning of each survey day by lowering a metal plate into the water at a fixed depth below the transducer and checked against the sensor display depth (USACE 2002). This quality control procedure served to verify the fathometer was functioning properly prior to collecting data along the planned survey lines.

Due to the range in depth that was encountered within the survey area, an assumed and constant water-column sound velocity of 4,922 feet/second (1,500 meters/second) was programmed within the echosounder. In order to determine actual water-column sound velocity and account for the variable speed of sound through the water column (which affect acoustic depth measurements), a conductivity-temperature-depth (CTD) profiler was used to acquire vertical profiles of the water-column. These CTD casts were obtained at the beginning, mid-point, and end of each survey day at locations displaying the deepest water depths to document changes in sound velocity within the entire water column over the PSR survey area. A total of five CTD profiles were collected during the survey, and the sound-velocity data obtained for each of these CTD cast was applied to raw echosounder data during post-processing.

Horizontal control checks of RTK GPS system accuracy were performed daily by comparing the results obtained by the Trimble R8 receiver unit to the known position of the pre-established reference point to ensure the desired level of horizontal and vertical accuracy were being achieved. During data acquisition, an alarm was set to alert surveyors of a horizontal dilution of precision 2.5 or greater, and surveying resumed when the geometry of satellites improved and the precision fell back to an acceptable limit. An elevation mask of 8 degrees above the horizon was applied to satellites through HYPACK® Max, and a minimum of four satellites were required for positioning throughout the survey.

3.4.4 Data Collection

Planned survey lines were loaded into HYPACK® Max Survey Program to aid in navigation during data collection, but actual survey lines were occasionally modified due to obstacles such as moored vessels, floating booms, and pilings. Lines were run at a maximum of 4 knots and preferably towards shore to ensure high data quality and reduce interference of prop wash with the transducer. The regular system of sounding lanes was supplemented by a series of crosslines, which verified the accuracy and reliability of surveyed depths and plotted locations. Crosslines were run perpendicular to all planned sounding lines.

The Hydrotrac® transducer produced a continuous analog record of the seafloor, transmitting approximately five digital depth values per second to HYPACK® Max. Within HYPACK® Max, the depth data were tagged with time and position to create and electronically record continuous depth records along each survey line. These records were viewed in real time to ensure adequate coverage of the survey area. A field log was also kept, recording date, weather, sea state, survey time, and start and stop times of logging with HYPACK® Max log file names.

3.4.5 Analysis

Since the RTK system applied height correctors associated with tidal variation in real time, the RTK data was post-processed in HYPACK® Max by identifying and removing outliers in sounding depths and applying sound velocity corrections. To verify the validity of the RTK derived vertical correctors, the raw bathymetric sounds were extracted from the data set and processed based upon observed water level data from the NOAA tide station 9447130 located in Elliott Bay. These data were obtained through NOAA's Center for Operational Oceanographic Products and Services. Six-minute tide data based on the MLLW vertical datum was downloaded from their web site (http://www.co-ops.nos.noaa.gov/) and were applied to the bathymetric data to reduce all depth soundings to the MLLW vertical datum.

After the raw bathymetric data were reduced to MLLW, they were examined in HYPACK® MAX's graphical editor to identify and remove outliers or spikes in soundings, as conducted on the RTK data. Once these two data sets were completed and compared, a difference of 1 foot (0.3 meter) between the RTK correctors and tidal correctors was identified. To compensate for this offset, the RTK correctors were then shifted to align with the observed tidal correctors.

To further analyze the data, a cross-check comparison of overlapping data was performed in order to verify the proper application of the correctors and to evaluate the overall consistency of the entire data set. Crossline comparison points were used in the HYPACK® Max Statistics routine to systematically compute the differences between all points from different survey lines that fall within a user-specified distance of each other.

The corrected sounding data were imported to ArcGIS 9.1 for gridding to a continuous raster surface. The Spatial Analyst extension for ArcGIS was used to explore the variance of the bathymetric data and determine the optimal interpolation parameters.

The primary analysis done on the final bathymetric gridded dataset was a depth-difference comparison against pre-construction bathymetric dataset completed by URS. Within ArcGIS 9.1, a bathymetric difference grid was generated between the most recent SAIC data and the URS pre-construction datasets to illustrate changes in seafloor topography over years and to evaluate total accumulation of sediment associated with capping.

3.5 Intertidal Beach Walk Survey Methods

The beach walk survey was conducted on transects located approximately 100 feet apart, as shown in Figure 3-3. Transects originated from the shoreline and extend into Elliott Bay through the intertidal zone to approximately 0 to 1.5 feet MLLW. The transect lines were designed to re-create previous efforts and provide a strong basis of comparison to previous surveys so any significant changes in topography could be quantified. The beach walk survey utilized the same RTK Trimble differential GPS unit as the bathymetric survey, ensuring compatible data for post processing. Photographs using a digital camera and tripod were taken from the waterline while looking toward the shoreline and toward the water from approximately the mean higher high water (MHHW) line. The photographs collected during the beach walk survey are provided in Appendix F. Visual observations made during the beach walk are included in the captions of the photographs.

Positioning for the topographic survey was accomplished using the same Trimble RTK DGPS units employed as part of the bathymetric survey, which ensured compatible data to the underwater soundings. Prior to the survey, equipment precision was verified by repeated measures at a nearby monument. The GPS antenna was mounted on a pole at a fixed height above the ground (2 meters), which was later removed in the calculations made with the handheld Trimble TSC-2 survey controller that displayed and logged the position and height data during the beach walk element of the survey. Upon completion of the survey, the beach walk elevation data were processed similar to the bathymetric data (Section 3.4.5). Due to the elevation disagreement of the RTK bathymetric correctors and tidal correctors, the beach walk data were also shifted 1 foot (0.3 meter) to match the offset of the bathymetric data. The corrected beach walk data were imported to ArcGIS 9.1 and displayed as point measurements.

The primary analysis performed with the final elevation dataset was to compare current elevations against the available pre-construction transect dataset. Since data points between the two surveys did not match exactly, the data points in proximity to each other were selected. If there were no data points in the vicinity to use for comparison, the URS points were excluded. Once similar data points were selected, transect data from each elevation survey was graphed and compared to illustrate changes in intertidal beach face.

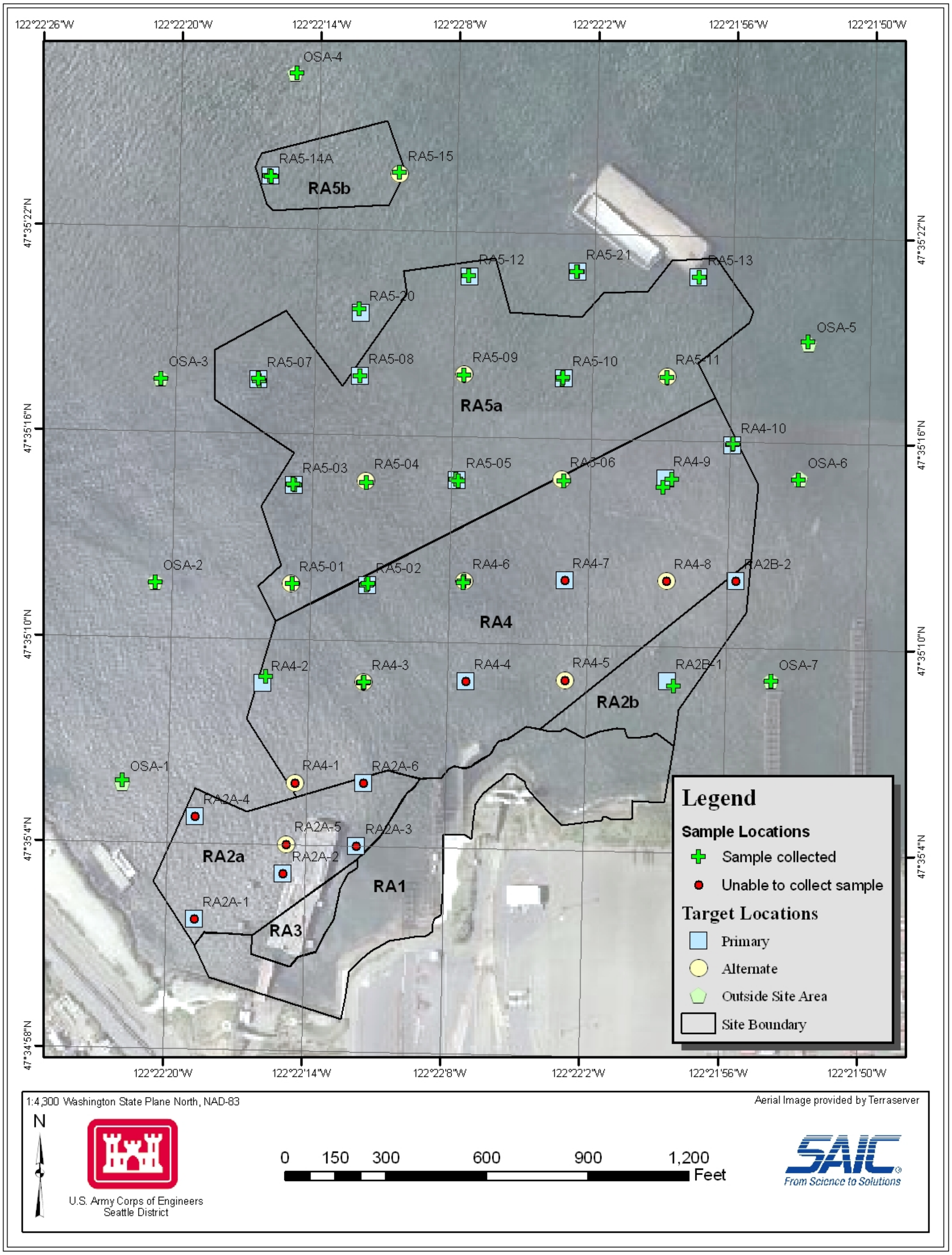


Figure 3–1. Actual Surface Sediment Sampling Locations for the PSR Superfund Site

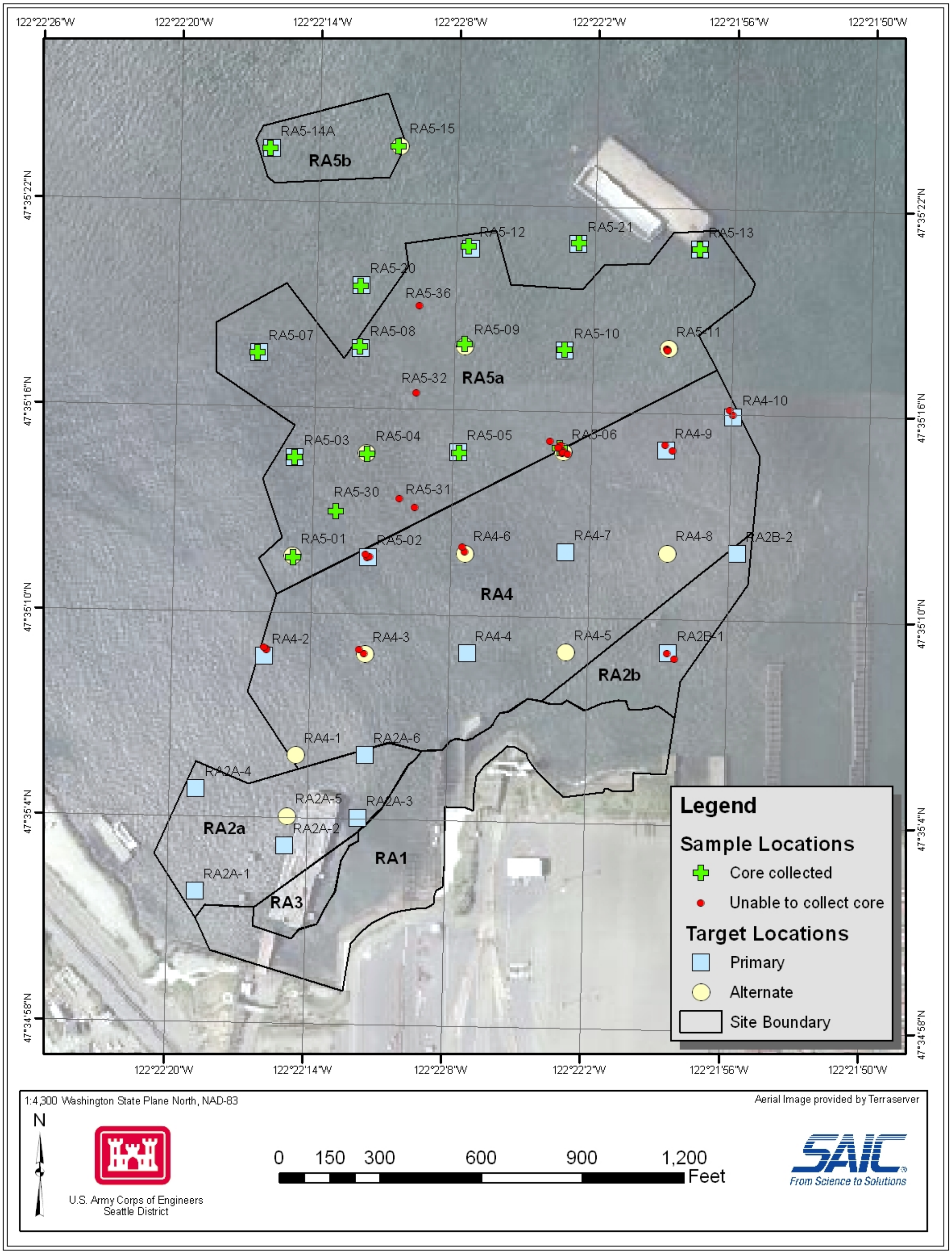


Figure 3–2. Actual Subsurface Coring Locations for the PSR Superfund Site

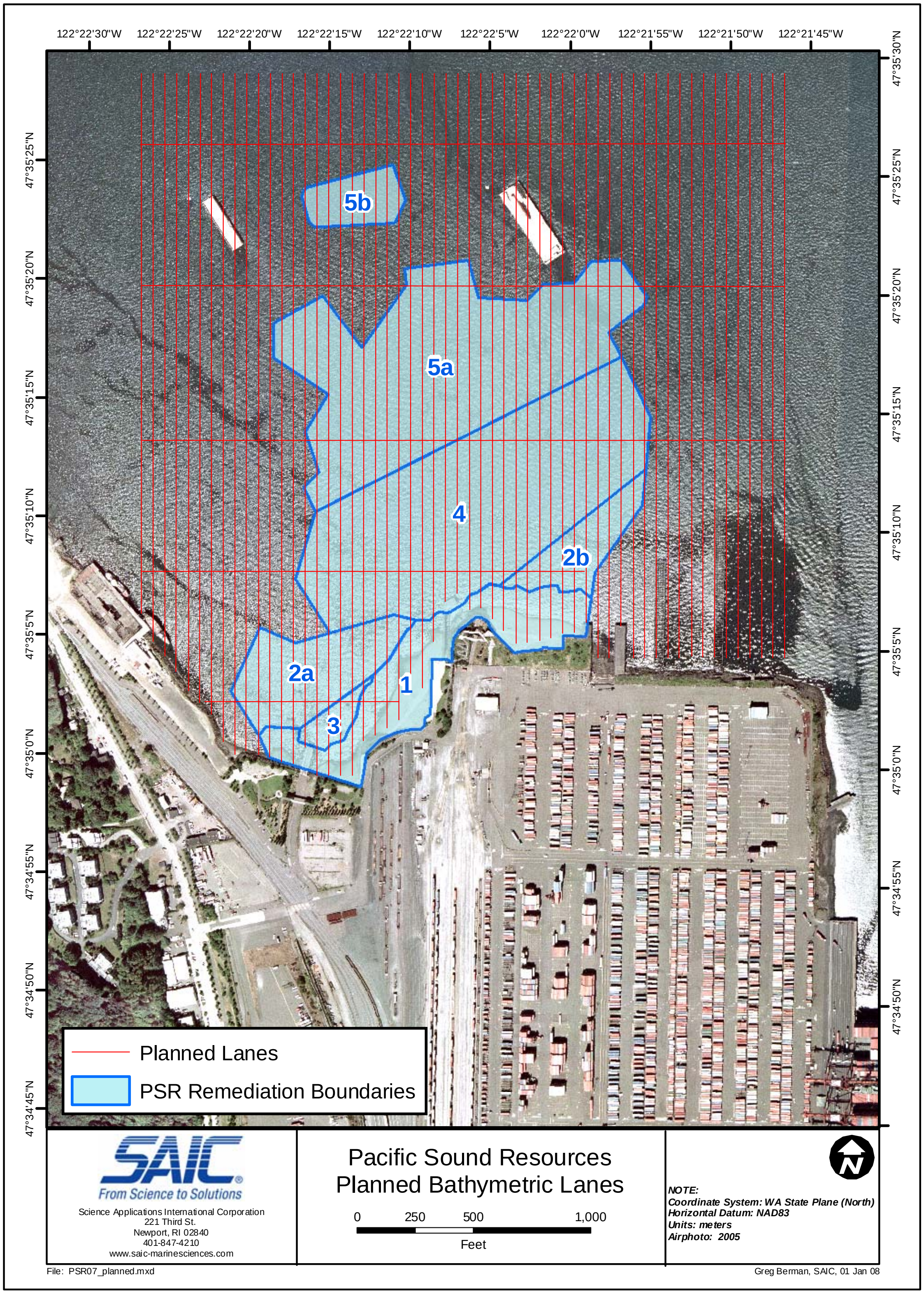


Figure 3–3. Planned Bathymetric Survey Lanes

4.0 Data Results

This section provides the results for the surface sediment chemistry, determination of cap thickness, biological testing, bathymetric survey, and beach walk survey.

4.1 Chemistry Results

A summary of the results of the surface sediment chemical analysis are discussed below and are presented in full in the Chemical Data Final Report (Appendix B). No subsurface sediment samples were submitted for chemical analysis.

4.1.1 Results

The surface sediment data results (Table 4-1, Figure 4-1, and Appendix B) indicate that only one of the surface sediment samples collected from within RA2, RA4, and RA5 capped areas exceeded the SMS sediment criteria (Table 4-1). The duplicate sample RA5-14A-S-D exceeded the SMS for total PCBs with a concentration of 18.01 mg/kg organic carbon (OC). The field sample RA5-14A-S had a concentration of 9.63 mg/kg OC and did not exceed the SQS. It is not clear why there is such a difference between the duplicates. They were both collected on the same day, but the duplicate was analyzed in a separate batch nearly two months after the field sample. Two potential reasons for the difference could be due to sample heterogeneity for the relatively coarse grain size of the samples (30 percent fines) or the co-elution of the PCB aroclors.

Only Aroclor 1254 was detected in RA5-14A-S, while Aroclors 1242, 1254, and 1260 were detected in the duplicate (RA5-14A-S-D). The congeners that make up these Aroclor mixtures can elute at the same time from the gas chromatograph. When multiple Aroclors are detected in a sample, double counting of PCB congeners can create an artificially high concentration (CAS case narratives, Appendix C). However, despite the difference between results, the location RA5-14A-S should be considered as exceeding the SQS for total PCBs.

Several analytes exceeded the SMS in samples collected from OSA locations. The SQS was exceeded in the sample OSA-01-S for indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene. The sample OSA-07-S exceeded the SMS SQS for zinc, indeno(1,2,3-cd) pyrene, and total PCBs and the SMS CSL for chromium. These higher concentrations in the OSA versus the remedial area are indicative of the effectiveness of the cap material.

Two additional samples, OSA-06-S and RA2B-1-S, exceeded the SQS for 1,2,4-trichlorobenzene and hexachlorobenzene. However, these analytes were not detected in these samples. The analytes exceeded the SMS due to OC normalization using TOC below 0.5 percent. In cases where low TOC values unavoidably cause SMS criteria to be exceeded, the dry weight results are compared to Puget Sound Apparent Effects Thresholds (AETs) (Ecology 1996, 2003). In this case, the detection limit for both compounds is under the AETs of 31 μg/kg DW and 22 μg/kg DW for 1,2,4-trichlorobenzene and hexachlorobenzene, respectively.

Table 4–1. Summary of the Surface Sediment Chemistry Results Comparison to SMS Numeric Criteria

	Sediment Quality Standards	Cleanup Screening Levels	PSR07-OSA-1-S	PSR07-OSA-6-S	PSR07-OSA-7-S	PSR07-RA5-14A-S	PSR07-RA5-14A-S-D
			8/7/07	8/7/07	8/7/07	8/8/07	8/8/07
Metals (mg/kg dry wt)							
Chromium	260	270	26.1	8.52	**293**	38.4	62.60
Zinc	410	960	70.7	28.2	*452*	89.8	150.00
Non-Ionizable Organic Compounds (mg/kg OC)							
Indeno(1,2,3-cd)pyrene	34	88	*42.15*	10.75	*35.34*	6.52	4.66
Benzo(g,h,i)perylene	31	78	*34.71*	9.75	29.31	5.26	4.49
Miscellaneous Extractable Compounds (mg/kg OC)							
Total PCBs	12	65	4.96	8.75	*12.07*	9.63	*18.01*

Notes:
Italic font indicates the analyte exceeds the SMS SQS criteria.
Bold font indicates the analyte exceeds the SMS CSL criteria.
U: analyte not detected.

4.1.2 Data Quality

Data quality met the standards of precision, accuracy, representativeness, and completeness for most samples (Appendix B). Precision is a measure of mutual agreement among individual measurements of the same property under prescribed conditions and accuracy is the degree of agreement of a measurement with an accepted reference or true value. Both precision and accuracy were met with only minor deviations of PSEP criteria by a few analytes.

Representativeness expresses the degree to which data accurately and precisely represent an actual condition or characteristic at a particular sampling point through the comparison of field duplicates. For the metals, representativeness between samples RA5-14A-S and RA5-8-S and their respective duplicates was poor, likely due to heterogeneous samples. Representativeness was also poor for the SVOCs and PCBs sample RA5-14A-S and its duplicate. The field duplicates for these compound classes were analyzed from the archive sample nearly two months after the initial analysis of the field samples. It cannot be determined if the poor representativeness is due to the heterogeneity of the field sample or analytical variability due to being run in different batches.

The most important measure of completeness is the number of usable results versus the number of samples analyzed. With the exception of grain size distribution for sample RA4-2-S, all results are usable. The sample RA4-2-S has a discrepancy in the sand fraction percentages between the original sample and its respective field replicates that appears to be due to analytical error. The duplicate and triplicate analyses are in agreement. This discrepancy did not affect any of the subsequent data evaluation contained herein.

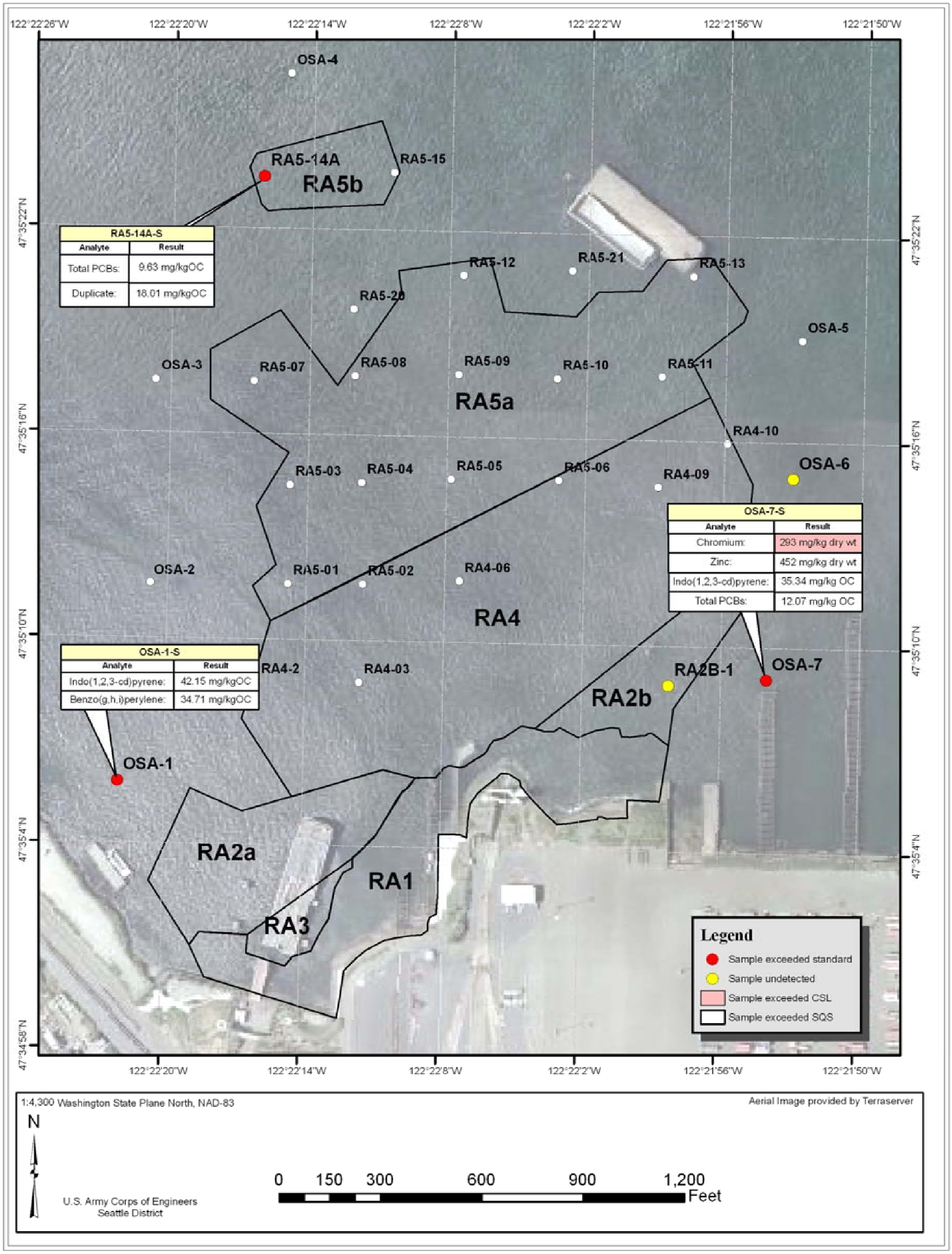


Figure 4–1. Chemistry Exceeding SMS Numeric Criteria

4.2 Cap Thickness

The results of the cap thickness determination are provided in Table 4-2. A graphical representation of cap thickness is presented in Figure 4-2. To extrapolate the cap thickness RA5 boundary, cap thickness at the OSA sites was assumed to be zero. The sediment cap design specifications are for the cap to be between 27 and 40 inches thick. The results of the 2007 monitoring event show a cap thickness ranging from 0 to 21.3 inches thick (Table 4-2), indicating that no portion of the cap in RA5 met the minimum cap depth criteria of 27 inches. The average cap thickness was 9.7 ± 6 inches or about 36 percent of design specifications.

It is possible the measurements of cap thickness are understated as they do not take into account the percent recovery reflecting compaction within the core tube samples (actual core recovery/core penetration). The calculation of percent recovery was not possible as penetration depth was indeterminable due to a combination of the vibracorer equipment used and the water depth at the site. However, it is unlikely that the relatively consolidated fraction representing the cap (i.e., coarse sand) would have significant compaction within the core tube. A reasonable estimation of 25 percent compaction during sampling would indicate a cap material thickness of approximately 1.3 times the measurements provided in Table 4-2 (Anchor 2005). If this rate of compaction were true for all samples, only one (RA5-03-C) would meet the design specifications.

A comparison to results from 2005 and 2006 indicates a slight decrease in the mean cap thickness. Figure 4-3 presents the comparison between the 2005 Anchor Environmental survey and the surveys conducted by SAIC in 2006 and 2007. The mean thickness was 13.9 inches in 2005, 11.5 inches in 2006, and 9.7 inches in 2007. There was no statistically significant difference in the overall cap thickness ($P = 0.50$) between years due to high variability around the means. The proximity of sampling stations between years may explain differences between the means. Figure 4-4 indicates the sampling location and distance between the same stations that were occupied in all three years. Most stations in 2007 were sampled within 20 feet of the locations sampled in 2006 and 2005. Four stations (RA5-01, RA5-05, RA5-07, and RA5-09) in 2007 were sampled greater than 20 feet away from the 2006 location. Based on the consistent variance in measurement, the monitoring data suggest high spatial variability in cap thickness across RA5. Also, the decrease in the mean cap thickness from 2005 to 2007 indicates compaction occurring as cap material settles over time.

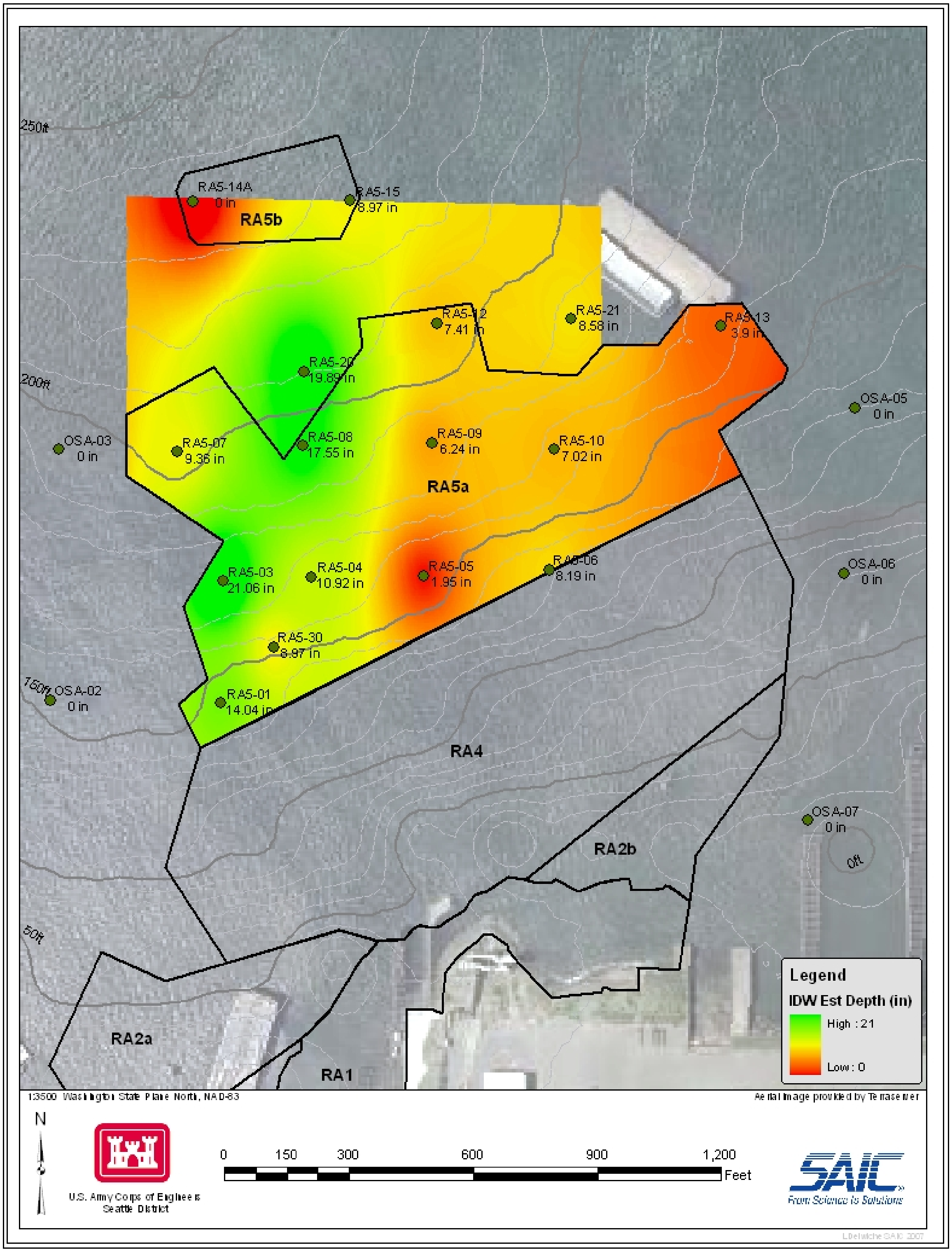


Figure 4–2. Cap Thickness at Pacific Sound Resources Remedial Area 5A based on 2007 Monitoring Results

Table 4–2. 2007 Summary of Through-Cap Cores

Core ID	Total Recovered Core Length (cm)	Estimated RA5 Cap Material Thickness (cm)	Estimated Contribution of RA4 Cap Material (cm)	Total Estimated Cap Thickness[1] (cm)	Total Estimated Cap Thickness (in)	Percent of Cap Design Thickness[2] (%)	Meets Design Criteria	Description
RA5-01-C	91	36	0	36	14.17	52	No	Cap material present over native sediment
RA5-03-C	145	54	0	54	21.26	79	No	Cap material present over contaminated sediment
RA5-04-C	107	25	3	28	11.02	41	No	Cap material present over native sediment
RA5-05-C	69	5	0	5	1.97	7	No	Cap material present over contaminated sediment
RA5-06-C	33	21	0	21	8.27	31	No	No evidence of native material in core
RA5-07-C	142	19	5	24	9.45	35	No	0–24 cm appears to be cap material, but looks mixed/disturbed - may be coring artifact
RA5-08-C	66	45	0	45	17.72	66	No	Native material evident in core catcher
RA5-09-C	63	13	3	16	6.30	23	No	Cap material present over native sediment
RA5-10-C	119	18	0	18	7.09	26	No	Cap material present over native sediment
RA5-12-C	109	19	0	19	7.48	28	No	Cap material present over native sediment
RA5-13-C	147	10	0	10	3.94	15	No	Cap material present over native sediment
RA5-14A-C	89	0	0	0	0	0	No	No evidence of cap material in core
RA5-15-C	41	23	0	23	9.05	34	No	Cap material present over native sediment
RA5-20-C	63	34	17	51	20.08	74	No	Cap material present over native sediment
RA5-21-C	48	19	3	22	8.66	32	No	Cap material present over native sediment
RA5-30-C	33	23	0	23	9.05	33	No	Evidence of RA4 cap material in core catcher (3–5 cm)

Notes:

1 The cap design specifications for RA5 were a minimum thickness of 27 inches (24 inches following consolidation), with a 13-inch operational allowance, the RA5 cap should range from 27 to 40 inches as-placed.

2 Percent cap thickness based on 27-inch minimum depth.

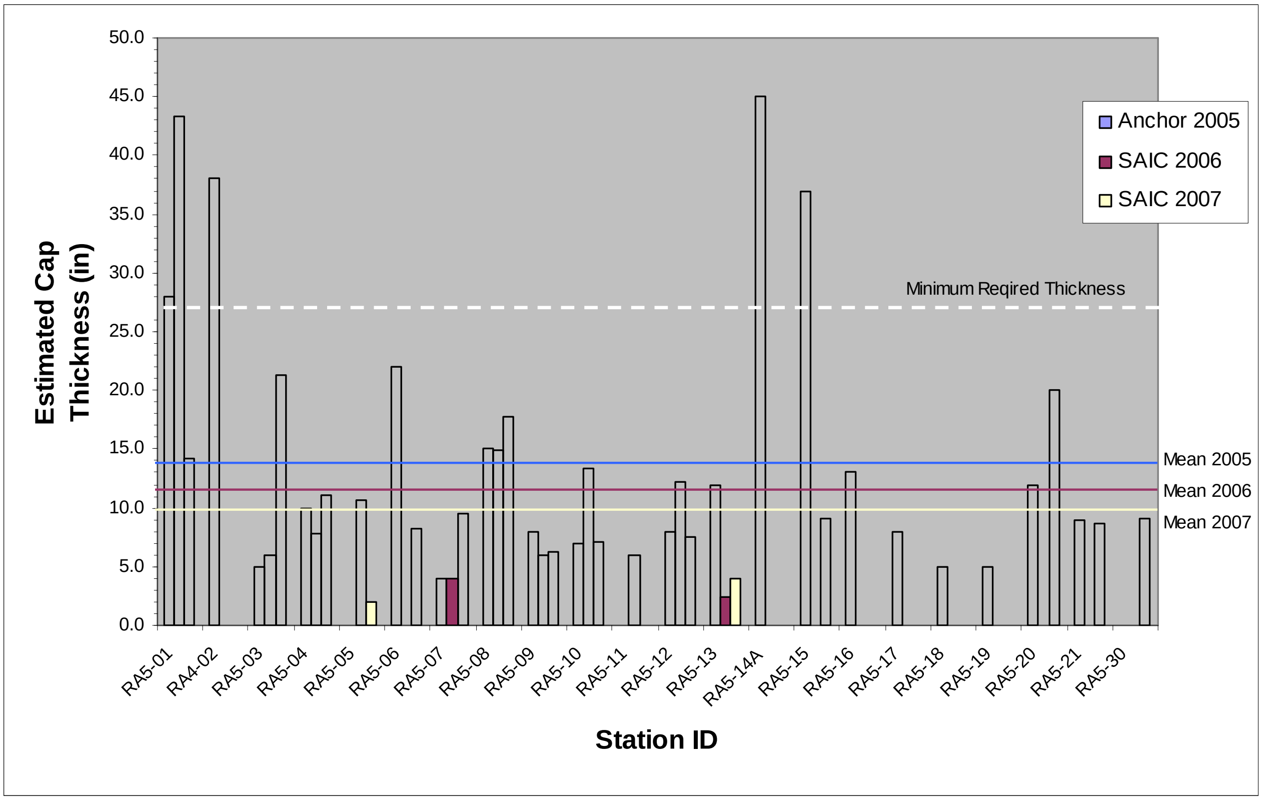


Figure 4–3. Comparison of Cap Thickness at Pacific Resources Remedial Area 5A for 2005, 2006, and 2007 Monitoring Events

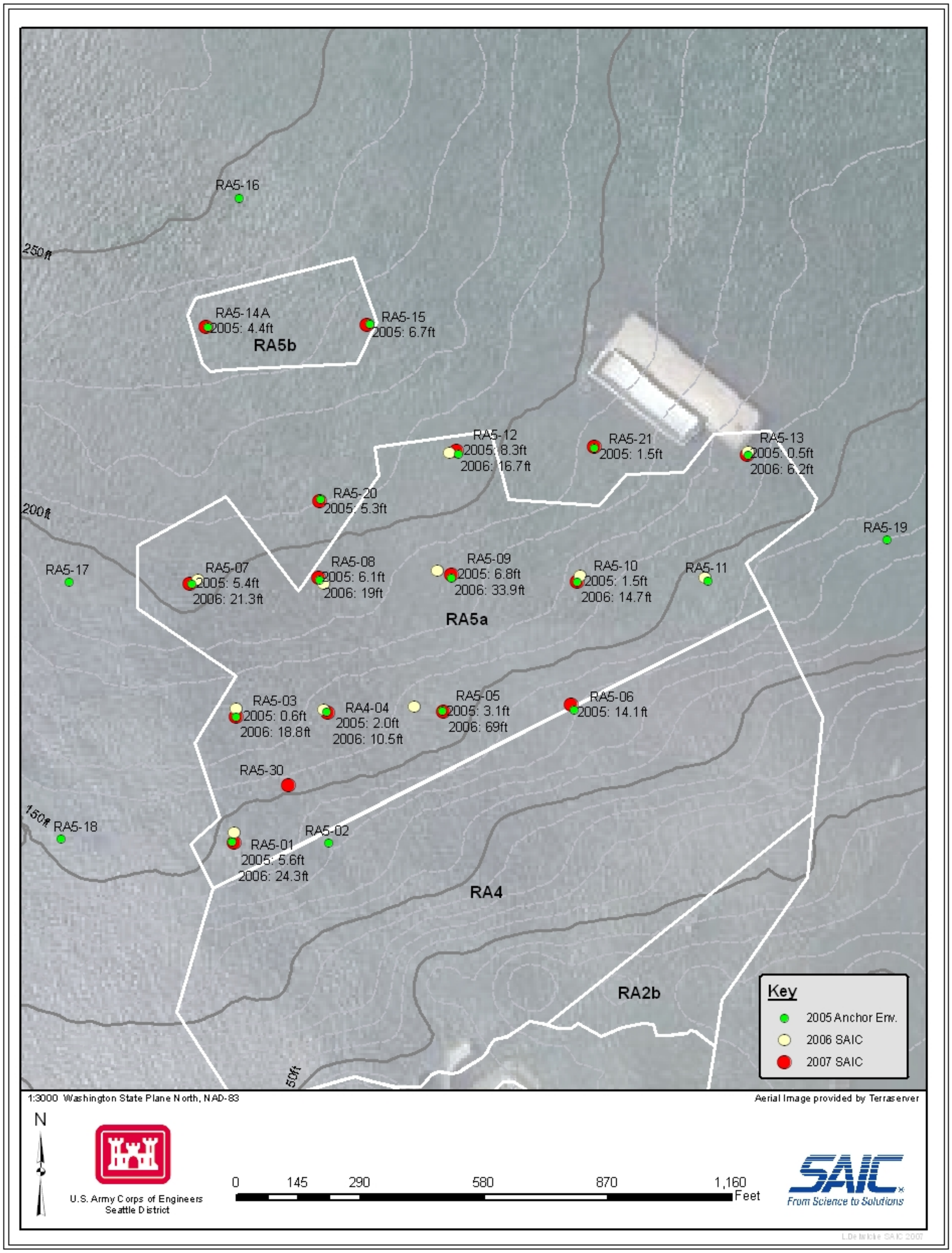


Figure 4–4. Sampling Location for the 2007 Survey and Distance between the Same Station that was Occupied in 2005 (Anchor 2005) and in 2006 (SAIC 2006)

4.3 Biological Testing Results

The confirmatory biological testing was performed on 23 sediment samples from the PSR capped area and 3 reference sediments collected from Carr Inlet. The bioassays conducted included:

1. 10-day amphipod mortality (*Rhepoxynius abronius*),
2. 48-hour larval development (*Mytilus galloprovincialis*), and
3. 20-day juvenile polychaete growth (*Neanthes arenaceodentata*).

The following sections summarize the results of the confirmatory biological testing. The bioassay laboratory report is provided in Appendix E.

4.3.1 *Bioassay Water Quality Results*

The water quality test condition protocols and summary of daily measurements are presented in Table 4-3. The temperature, salinity, dissolved oxygen, and pH were all within control limits and acceptable ranges, with a few a minor exceptions. The temperature was slightly above the control limit for a single daily measurement in three replicates for the amphipod mortality bioassay. The salinity was slightly above the control limit in several daily measurements for the Juvenile polychaete growth bioassay. Both of these exceptions were still within the tolerable ranges of the species. The water quality measurements for ammonia (interstitial and overlying) and sulfides (interstitial) are presented in Table 4-4. The total ammonia and sulfide concentrations were all below levels of potential concern as a confounding factor in bioassay test results, with the exception of one reference sediment. The interstitial ammonia concentration measured in reference sediment was 18.2 mg/L. The interstitial ammonia concentration in the reference sediment exceeds the threshold for conducting ammonia reference toxicant tests (> 15 mg/L for *R. abronius*) but was below the threshold for considering sample purging (> 30 mg/L for *R. abronius*). Based on the water quality measurements, there is no reason to believe there were any adverse effects on test organisms due to laboratory test conditions.

Table 4–3. Water Quality Test Results Compared to Test Control Limits (Ecology 2003)

Test (*Test Species*)	Control Limits/Test results	Temperature	Salinity	Dissolved Oxygen	pH[3]
Amphipod Mortality (*R. abronius*)	Control Limits	15 ± 1°C	28 ± 1 ppt	n/a[2]	---
	Test Results[1]	14.0 – 16.4°C	27.2 – 29.7	7.59 – 8.11 mg/L	5.9 – 8.2
Larval Development (*M. galloprovincialis*)	Control Limits	16 ± 1°C	28 ± 1 ppt	> 60% saturation	---
	Test Results[1]	15.1 - 16.1°C	27.1– 28.1 ppt	6.3 – 7.8 mg/L	7.61 – 7.93
Juvenile Polychaete Growth (*N. arenaceodentata*)	Control Limits	20 ± 1°C	28 ± 2 ppt	n/a[2]	---
	Test Results[1]	19.1 – 20.9°C	27.4 – 30.8 ppt	5.3 – 8.1 mg/L	7.38 – 8.26

Notes:
[1] Water quality test results are for reference and test sediment parameters only; does not include negative control results.
[2] Continuous aeration is required by the protocol, so the dissolved oxygen should not be a cause of concern.
[3] pH is required for water quality monitoring but does not have explicit control limits.

Table 4–4. Water Quality Measurements of Total Ammonia and Sulfides

Test (*Test Species*)	Interstitial Ammonia Total NH_3 (mg/L)	Overlying Ammonia Total NH_3 (mg/L)	Sulfides (mg/L)
Amphipod Mortality (*R. abronius*)	<1.0 – 18.2[1]	<1.0 – 3.4[1]	<0.01 – 0.071[3]
Larval Development (*M. galloprovincialis*)	n/a	<1.0	n/a
Juvenile Polychaete Growth (*N. arenaceodentata*)	<1.0 – 18.2[1,2]	<1.0 – 4.9[1]	<0.01 – 0.042[4]

Notes:
n/a: not applicable
[1] Maximum ammonia concentrations were measured in the reference sediment CR-23.
[2] Interstitial ammonia concentrations were not measured separately for juvenile polychaete test.
[3] Sulfides measurement is interstitial water.
[4] Sulfides measurement is overlying water.

4.3.2 Negative Control and Reference Sediment Performance Results

The performance results of the negative control and reference sediments for each bioassay are presented in Table 4-5. The negative control and reference sediment performance standards were met for both the amphipod mortality and juvenile polychaete growth tests. The negative control performance standard was met for the larval development test. There is not an SMS reference performance standard for the larval development test. Therefore, the test results for the amphipod mortality, larval development, and juvenile polychaete bioassays should be considered valid for the purposes of the SMS confirmatory biological tests.

The reference sediments are used in comparison with test sediments for interpreting the results of the bioassays. The percent fines, the total of the silt and clay grain size fractions, are used for pairing the appropriate reference sediment with a given test sediment (Table 4-6). The percent fines for the three reference samples were: CR-02 = 91.2 percent, CR-23 = 50.86 percent, and MSMP-43 = 5.7 percent. The percent fines for the test sediments ranged from 8.63 to 38.89 percent. Test sediments with percent fines less than 28.28 percent were compared to reference sediment MSMP-43 and those with percent fines between 28.28 and 71.03 percent were compared to reference sediment CR-23. Since no test sediments exceeded 71.03 percent fines, reference sediment CR-02 was not used for interpreting results. It is recommended that the reference sediments should have percent fines within 20 percent of the test sediment percent fines (Ecology 2003). Therefore, the test sediments with percent fines between 25.7 and 30.86 percent are not within the recommendations for reference comparisons. Five test sediments (RA5-09, RA5-13, RA5-14A, RA5-15, and RA5-20) all had percent fines > 20 percent different from the percent fines of the reference sediments. Therefore, for these five sediments a second comparison using a pooled reference (combined data results for MSMP-43 and CR-23) was also performed. The TOC results for reference and test sediments are included in Table 4-6 for comparison.

Table 4–5. Negative Control Performance Standards and Test Results

Test (*Test Species*)	Negative Control Performance Standard	Negative Control Results[1]	Reference Sediment Performance Standard	Reference Sediment Results
Amphipod Mortality (*R. abronius)*	$M_C \leq 10\%$	3.0 ± 4.5 %	$M_R \leq 25\%$	CR02: 2.0 ± 2.7%; MSMP-43: 4.0 ± 4.2; CR23: 14.0 ± 20.7
Larval Development (*M. galloprovincialis*)	$N_C \div I \geq 0.70$	97.8 ± 4.8 %	$N_R \div N_C \geq 0.6565$	CR02: 0.80 MSMP-43: 0.94 CR23: 0.71
Juvenile Polychaete Growth (*N. arenaceodentata*)	$M_C \leq 10\%$ and $MIG_C \geq 0.38$[2]	8.0 ± 11.0%; 0.499	$MIG_R \div MIG_C \geq 0.80$	CR02: 99.6%; MSMP-43: 99.6%; CR23: 120.5%

Notes:
M = mean mortality.
N = mean normal development survival in seawater control.
I = initial count = 262.
MIG = mean individual growth rate (mg/individual/day)
Subscripts: R = reference; C = negative control
1 Result ± standard deviation.
2 Target MIGc is 0.72 mg/individual/day; the test is considered to be failed if the Control MIG is less than 0.38 mg/individual/day.

Table 4–6. Grain Size and TOC Results for Determining Reference Sediments Comparisons

Sample ID	Percent Fines (silt + clay)	Total Organic Carbon (%)	Reference Sediment for Comparison[1]
Reference CR02	91.2	1.31	n/a
Reference MSMP-43	5.70	0.23	n/a
Reference CR23	50.86	0.56	n/a
RA2B-1	8.63	0.28	MSMP-43
RA4-2	14.34	0.52	MSMP-43
RA4-3	14.00	1.51	MSMP-43
RA4-6	13.21	0.76	MSMP-43
RA4-9	11.70	1.14	MSMP-43
RA4-10	12.75	0.68	MSMP-43
RA5-1	32.29	1.88	CR-23
RA5-2	14.87	1.45	MSMP-43
RA5-3	38.89	1.5	CR-23
RA5-4	12.42	1.19	MSMP-43
RA5-5	21.70	0.85	MSMP-43
RA5-6	15.79	1.26	MSMP-43
RA5-7	34.27	1.45	CR-23
RA5-8	22.55	1.93	MSMP-43
RA5-9	27.55	1.69	MSMP-43/pooled[2]
RA5-10	24.90	0.95	MSMP-43
RA5-11	23.39	2.16	MSMP-43
RA5-12	25.61	1.26	MSMP-43
RA5-13	30.07	1.08	CR-23/pooled[2]
RA5-14A	30.00	1.35	CR-23/pooled[2]
RA5-15	27.94	1.11	MSMP-43/pooled[2]
RA5-20	25.88	1.39	MSMP-43/pooled[2]
RA5-21	24.64	0.98	MSMP-43

Notes:

1 Test sediments with percent fines < 28.28 percent are paired with MSMP-43, between 28.28 and 71.03 percent are paired with CR-23, and > 71.03 percent would have been paired with CR-02.

2 Test sediments with percent fines more than 20 percent different from the reference sediment percent fines were also evaluated against a pooled reference, which consisted of the combined results from the MSMP-43 and CR-23 reference sediments.

4.3.3 Positive Control Results

The results of the reference toxicant tests for the three bioassays are provided in Table 4-7. The EC50 values fell within the acceptable range of mean ± two standard deviations for historical reference toxicant data generated by the Nautilus Environmental laboratory. The reference toxicant results indicate the test organisms appeared to be sufficiently sensitive for demonstrating a toxic response (Nautilus 2007).

Table 4–7. Reference Toxicant Results

Test (*Test Species*)	Reference Toxicant	Endpoint	EC50	95% confidence interval	Laboratory Historical Range (mean ± 2SD)
Amphipod Mortality (*R. abronius*)	cadmium chloride	96-hour survival	1.3 mg/L Cd	1.1 – 1.5 mg/L Cd	0.3 – 1.53 mg/L Cd
Larval Development (*M. galloprovincialis*)	copper chloride	Normality	9.4 µg/L Cu	9.0 – 9.8 µg/L Cu	5.1 – 14.5 µg/L Cu
Juvenile Polychaete Growth (*N. arenaceodentata*)	cadmium chloride	96-hour survival	17.6 mg/L Cd	9.9 – 38.6 mg/L Cd	4.58 – 22.9 mg/L Cd

4.3.4 *Amphipod Mortality Bioassay*

The amphipod mortality test was initiated on August 21, 2007, using test organisms (*R. abronius*) obtained from West Beach, Whidbey Island, WA, collected by Puget Sound Organisms. The results of the amphipod mortality bioassay are presented in Tables 4-8 and 4-9. The amphipod mean mortality ranged from 3 to 16 percent in the test sediments. All 23 test sediments passed both the SMS, SQS, and CSL biological effects interpretive criteria for the amphipod mortality bioassay. The bioassay results are displayed in Figure 4-5.

Table 4–8. Amphipod Mortality Bioassay (*R. abronius*) Results and Evaluation Guidelines

Sample ID	Percent Mortality[1]	Mean Mortality[2]	Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				–	M_T vs M_R SD; $p = 0.05$: significant? (test)	$M_T - M_R > 25\%$ and M_T vs M_R SD ($p = 0.05$) Pass/Fail	$M_T - M_R > 30\%$ and M_T vs M_R SD ($p = 0.05$) Pass/Fail
Control	0.0 0.0 0.0 5.0 10.0	3.0 ± 4.5	n/a	n/a	n/a	n/a	n/a
Reference CR02	0.0 0.0 0.0 5.0 5.0	2.0 ± 2.7	n/a	n/a	n/a	n/a	n/a
Reference MSMP-43	0.0 0.0 5.0 5.0 10.0	4.0 ± 4.2	n/a	n/a	n/a	n/a	n/a
Reference CR23	0.0 10.0 50.0 10.0 0.0	14.0 ± 20.7	n/a	n/a	n/a	n/a	n/a

Sample ID	Percent Mortality[1]	Mean Mortality[2]	Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				–	M_T vs M_R SD; p = 0.05: significant? (test)	$M_T - M_R > 25\%$ and M_T vs M_R SD (p = 0.05)	$M_T - M_R > 30\%$ and M_T vs M_R SD (p = 0.05)
						Pass/Fail	Pass/Fail
RA2B-1	0.0 5.0 10.0 15.0 0.0	6.0 ± 6.5	MSMP-43	2.0	No (t-test)	Pass	Pass
RA4-2	0.0 15.0 5.0 5.0 5.0	6.0 ± 5.5	MSMP-43	2.0	No (t-test)	Pass	Pass
RA4-3	20.0 25.0 5.0 15.0 5.0	14.0 ± 8.9	MSMP-43	10.0	Yes (Mann-Whitney)	Pass	Pass
RA4-6	0.0 5.0 0.0 5.0 10.0	4.0 ± 4.2	MSMP-43	0.0	No (Mann-Whitney)	Pass	Pass
RA4-9	5.0 0.0 5.0 10.0 0.0	4.0 ± 4.2	MSMP-43	0.0	No (Mann-Whitney)	Pass	Pass
RA4-10	20.0 10.0 10.0 5.0 5.0	10.0 ± 6.1	MSMP-43	6.0	Yes (t-test)	Pass	Pass
RA5-1	0.0 20.0 10.0 10.0 0.0	8.0 ± 8.4	CR-23	-6.0	No (t-test)	Pass	Pass
RA5-2	0.0 5.0 5.0 0.0 5.0	3.0 ± 2.7	MSMP-43	-1.0	No (Mann-Whitney)	Pass	Pass
RA5-3	15.0 25.0 0.0 5.0 20.0	13.0 ± 10.4	CR-23	-1.0	No (t-test)	Pass	Pass

Sample ID	Percent Mortality[1]	Mean Mortality[2]	Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				–	M_T vs M_R SD; p = 0.05: significant? (test)	$M_T - M_R > 25\%$ and M_T vs M_R SD (p = 0.05)	$M_T - M_R > 30\%$ and M_T vs M_R SD (p = 0.05)
						Pass/Fail	Pass/Fail
RA5-4	0.0 5.0 5.0 10.0 0.0	4.0 ± 4.2	MSMP-43	0.0	No (Mann-Whitney)	Pass	Pass
RA5-5	0.0 10.0 15.0 15.0 0.0	8.0 ± 7.6	MSMP-43	4.0	No (Mann-Whitney)	Pass	Pass
RA5-6	0.0 15.0 15.0 20.0 0.0	10.0 ± 9.4	MSMP-43	6.0	No (t-test)	Pass	Pass
RA5-7	5.0 25.0 0.0 15.0 5.0	10.0 ± 10.0	CR-23	-4.0	No (t-test)	Pass	Pass
RA5-8	15.0 0.0 5.0 5.0 10.0	7.0 ± 5.7	MSMP-43	3.0	No (t-test)	Pass	Pass
RA5-9	10.0 0.0 5.0 0.0 15.0	6.0 ± 6.5	MSMP-43	2.0	No (t-test)	Pass	Pass
RA5-10	0.0 0.0 10.0 0.0 10.0	4.0 ± 5.5	MSMP-43	0.0	No (Mann-Whitney)	Pass	Pass
RA5-11	0.0 10.0 0.0 0.0 15.0	5.0 ± 7.1	MSMP-43	1.0	No (Mann-Whitney)	Pass	Pass
RA5-12	5.0 10.0 10.0 5.0 5.0	7.0 ± 2.7	MSMP-43	3.0	No (t-test)	Pass	Pass

Sample ID	Percent Mortality[1]	Mean Mortality[2]	Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				–	M_T vs M_R SD; p = 0.05: significant? (test)	$M_T - M_R > 25\%$ and M_T vs M_R SD (p = 0.05)	$M_T - M_R > 30\%$ and M_T vs M_R SD (p = 0.05)
						Pass/Fail	Pass/Fail
RA5-13	20.0 10.0 10.0 30.0 5.0	15.0 ± 10.0	CR-23	1.0	No (t-test)	Pass	Pass
RA5-14A	20.0 15.0 5.0 0.0 25.0	13.0 ± 10.4	CR-23	-1.0	No (t-test)	Pass	Pass
RA5-15	5.0 10.0 40.0 5.0 5.0	13.0 ± 15.2	MSMP-43	9.0	No (t-test)	Pass	Pass
RA5-20	20.0 0.0 0.0 5.0 5.0	6.0 ± 8.2	MSMP-43	2.0	No (t-test)	Pass	Pass
RA5-21	15.0 15.0 15.0 5.0 30.0	16.0 ± 8.9	MSMP-43	12.0	Yes (t-test)	Pass	Pass

Notes:
SQS = sediment quality standards
CSL = cleanup screening level
M = mortality
SD = statistically different
Pass = meet SMS interpretive criteria
Fail = exceed SMS interpretive criteria
n/a = not applicable
Subscripts: R = reference; C = negative control; T = test sediment
1 Percent mortality observed in individual replicates.
2 Mean percent mortality ± standard deviation observed in test sample.
3 Reference sediment used for comparison.
4 Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All amphipod mortality data were arcsine transformed for statistical analysis.

Table 4–9. Amphipod Mortality Bioassay (*R. abronius*) Results Compared to Pooled Reference

Sample ID	Percent Mortality[1]	Mean Mortality[2]	Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				–	M_T vs M_R SD; p = 0.05: significant? (test)	$M_T - M_R > 25\%$ and M_T vs M_R SD (p = 0.05)	$M_T - M_R > 30\%$ and M_T vs M_R SD (p = 0.05)
						Pass/Fail	Pass/Fail
Pooled Reference (MSMP-43 + CR-23)	0.0 0.0 5.0 5.0 10.0 0.0 10.0 50.0 10.0 0.0	9.0 ± 15.1	n/a	n/a	n/a	n/a	n/a
RA5-9	10.0 0.0 5.0 0.0 15.0	6.0 ± 6.5	Pooled	-3.0	No (Mann-Whitney)	Pass	Pass
RA5-13	20.0 10.0 10.0 30.0 5.0	15.0 ± 10.0	Pooled	6.0	No (Mann-Whitney)	Pass	Pass
RA5-14A	20.0 15.0 5.0 0.0 25.0	13.0 ± 10.4	Pooled	4.0	No (t-test)	Pass	Pass
RA5-15	5.0 10.0 40.0 5.0 5.0	13.0 ± 15.2	Pooled	4.0	No (Mann-Whitney	Pass	Pass
RA5-20	20.0 0.0 0.0 5.0 5.0	6.0 ± 8.2	Pooled	-3.0	No (Mann-Whitney)	Pass	Pass

Notes:
SQS = sediment quality standards; CSL = cleanup screening level
M = mortality; SD = statistically different
Pass = meet SMS interpretive criteria; Fail = exceed SMS interpretive criteria
n/a = not applicable
Subscripts: R = reference; T = test sediment
[1] Percent mortality observed in individual replicates.
[2] Mean percent mortality ± standard deviation observed in test sample.
[3] Reference sediment used for comparison.

[4] Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All amphipod mortality data were arcsine transformed for statistical analysis.

4.3.5 *Larval Development Bioassay*

The larval development test was initiated on September 26, 2007, using test organisms (*M. galloprovincialis*) collected from Mission Bay Jetty, San Diego, CA. The results of the larval development bioassay are presented in Tables 4-10 and 4-11. The results for the larval development bioassay ranged from 60.1 to 83.9 percent normal survival for the test sediments. Sixteen of the twenty-three test sediments failed the SQS biological interpretive criteria for the larval development test. The bioassay results are displayed in Figure 4-5.

Based on the sediment chemistry, there were no contaminants (based on the SMS analyte list) measured at a concentration or frequency to indicate the potential for a toxic response. It is possible the source of toxicity is from a contaminant that was not analyzed as part of the monitoring program. It is also possible that the observed toxicity in the larval development test was an artifact of robustness of the organisms in the bioassay, resulting in a particularly sensitive test. The larval stock did not appear overly sensitive based on the results of the reference toxicant, but the biological laboratory report indicated that the larval test was initiated three times. The first two attempts by the laboratory were abandoned due to poor gamete quality, as late summer is a difficult time to obtain mussels in good spawning condition (Nautilus 2007). In addition, the stocking density for the completed larval test was only 14.8 larvae/mL, whereas the PSEP recommended stocking density is 20-40 larvae/mL. This represents a 26 to 63 percent under stocking for the initial larval density. It is suspected that the relatively poor quality of the gametes and low initial stocking density resulted in the poor performance of the larval development bioassay.

Table 4–10. Larval Development Bioassay (*M. galloprovincialis*) Results and Evaluation Guidelines

Sample ID	Percent Normal Survival[1]		Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				$N_T \div N_R$	N_T vs N_R SD; $p = 0.10$: significant? (test)	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.85$;	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.70$;
						Pass/ Fail	Pass/ Fail
Sea Water Control[2]	93.9 98.0 95.3 106.1 95.9	97.8 ± 4.8	n/a	n/a	n/a	n/a	n/a
Sediment Control[2]	66.2 70.9 73.0 71.6 66.2	69.6 ± 3.2	n/a	n/a	n/a	n/a	n/a
Reference CR02	62.2 85.8 81.1 74.3 89.2	78.5 ± 10.7	n/a	n/a	n/a	n/a	n/a

Sample ID	Percent Normal Survival[1]		Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				$N_T \div N_R$	N_T vs N_R SD; $p = 0.10$: significant? (test)	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.85$; Pass/ Fail	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.70$; Pass/ Fail
Reference MSMP-43	98.6 105.4 82.4 95.9 79.7	92.4 ± 11.0	n/a	n/a	n/a	n/a	n/a
Reference CR23	68.2 73.0 72.3 64.2 70.3	69.6 ± 3.5	n/a	n/a	n/a	n/a	n/a
RA2B-1	63.5 71.6 67.6 61.5 62.8	65.4 ± 4.1	MSMP-43	0.708	Yes (t-test)[5]	Fail	Pass
RA4-2	76.4 53.4 90.5 68.9 86.5	75.1 ± 14.8	MSMP-43	0.813	Yes (t-test)	Fail	Pass
RA4-3	81.1 75.0 66.9 58.8 68.9	70.1 ± 8.4	MSMP-43	0.759	Yes (t-test)	Fail	Pass
RA4-6	67.6 87.8 72.3 79.7 75.0	76.5 ± 7.7	MSMP-43	0828	Yes (t-test)	Fail	Pass
RA4-9	66.9 57.4 68.2 80.4 54.7	65.5 ± 10.2	MSMP-43	0.709	Yes (t-test)	Fail	Pass
RA4-10	70.3 65.5 73.6 64.2 56.8	66.1 ± 6.4	MSMP-43	0.715	Yes (t-test)[5]	Fail	Pass
RA5-1	77.7 70.9 77.0 68.2 77.0	74.2 ± 4.3	CR-23	1.066	No (Mann-Whitney)	Pass	Pass

Sample ID	Percent Normal Survival[1]		Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				$N_T \div N_R$	N_T vs N_R SD; $p = 0.10$: significant? (test)	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.85$; Pass/ Fail	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.70$; Pass/ Fail
RA5-2	74.3 80.4 83.8 83.8 54.7	75.4 ± 12.2	MSMP-43	0.816	Yes (t-test)	Fail	Pass
RA5-3	93.2 84.5 104.7 82.4 54.7	83.9 ± 18.5	CR-23	1.21	No (t-test)	Pass	Pass
RA5-4	95.3 79.1 67.6 67.6 58.1	73.5 ± 14.2	MSMP-43	0.795	Yes (t-test)	Fail	Pass
RA5-5	87.2 90.5 79.1 89.2 72.3	83.6 ± 7.8	MSMP-43	0.905	No (t-test)	Pass	Pass
RA5-6	81.1 75.7 57.4 57.4 64.2	67.2 ± 10.8	MSMP-43	0.727	Yes (t-test)	Fail	Pass
RA5-7	75.7 68.2 62.8 62.8 63.5	66.6 ± 5.5	CR-23	0.957	No (t-test)	Pass	Pass
RA5-8	73.6 70.3 93.9 68.2 81.1	77.4 ± 10.4	MSMP-43	0.838	Yes (t-test)	Fail	Pass
RA5-9	85.8 91.9 71.6 68.2 72.3	78.0 ± 10.3	MSMP-43	0.844	No (t-test)	Pass	Pass
RA5-10	82.4 68.2 70.9 75.0 81.8	75.7 ± 6.3	MSMP-43	0.819	Yes (t-test)	Fail	Pass

Sample ID	Percent Normal Survival[1]		Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				$N_T \div N_R$	N_T vs N_R SD; $p = 0.10$: significant? (test)	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.85$; Pass/ Fail	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.70$; Pass/ Fail
RA5-11	75.7 70.9 68.2 55.4 71.6	68.4 ± 7.7	MSMP-43	0.740	Yes (t-test)	Fail	Pass
RA5-12	77.7 75.0 70.9 74.3 75.0	74.6 ± 2.4	MSMP-43	0.807	Yes (t-test)[5]	Fail	Pass
RA5-13	75.0 70.9 85.1 77.7 83.8	78.5 ± 6.0	CR-23	1.128	No (t-test)	Pass	Pass
RA5-14A	54.1 55.4 45.9 63.5 84.5	60.7 ± 14.7	CR-23	0.872	No (t-test)	Pass	Pass
RA5-15	53.4 70.3 41.2 71.6 64.2	60.1 ± 12.8	MSMP-43	0.650	Yes (t-test)	Fail	Fail
RA5-20	84.5 71.6 75.0 74.3 66.9	74.5 ± 6.4	MSMP-43	0.806	Yes (t-test)	Fail	Pass
RA5-21	69.6 81.1 73.0 73.0 62.2	71.8 ± 6.8	MSMP-43	0.777	Yes (t-test)	Fail	Pass

Notes:
N = normal development; SD = statistically different
SQS = sediment quality standards; CSL = cleanup screening level
n/a = not applicable
Subscripts: R = reference; T = test sediment
[1] Percent normal survivors observed in individual replicates.
[2] Mean percent normal survivors ± standard deviation observed in test sample.
[3] Reference sediment used for comparison.
[4] Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All larval development data were arcsine transformed for statistical analysis, unless indicated otherwise.
[5] Rankit transformation used due to non-normality and non-homoscedasticity.

Table 4–11. Larval Development Bioassay (*M. galloprovincialis*) Results Compared to Pooled Reference

Sample ID	Percent Normal Survival[1]		Reference Sediment[3]	Comparison to Reference[4]		SQS	CSL
				$N_T \div N_R$	N_T vs N_R SD; p = 0.10: significant? (test)	N_T vs N_R SD (p = 0.10); $N_T \div N_R < 0.85$; Pass/ Fail	N_T vs N_R SD (p = 0.10); $N_T \div N_R < 0.70$; Pass/ Fail
Pooled Reference (MSMP-43 + CR-23)	98.6 105.4 82.4 95.9 79.7 68.2 73.0 72.3 64.2 70.3	81.0 ± 14.3	n/a	n/a	n/a	n/a	n/a
RA5-9	85.8 91.9 71.6 68.2 72.3	78.0 ± 10.3	Pooled	0.963	No (Mann-Whitney)	Pass	Pass
RA5-13	75.0 70.9 85.1 77.7 83.8	78.5 ± 6.0	Pooled	0.969	No (Rankits)	Pass	Pass
RA5-14A	54.1 55.4 45.9 63.5 84.5	60.7 ± 14.7	Pooled	0.749	Yes (Mann-Whitney)	Fail	Pass
RA5-15	53.4 70.3 41.2 71.6 64.2	60.1 ± 12.8	Pooled	0.742	Yes (Mann-Whitney)	Fail	Pass
RA5-20	84.5 71.6 75.0 74.3 66.9	74.5 ± 6.4	Pooled	0.920	No (Rankits)	Pass	Pass

Notes: N = normal development; SD = statistically different; n/a = not applicable
SQS = sediment quality standards; CSL = cleanup screening level
Subscripts: R = reference; T = test sediment
1 Percent normal survivors observed in individual replicates.
2 Mean percent normal survivors ± standard deviation observed in test sample.
3 Reference sediment used for comparison.
4 Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All larval development data were arcsine transformed for statistical analysis, unless indicated otherwise.
5 Rankit transformation used due to non-normality and non-homoscedasticity.

4.3.6 *Juvenile Polychaete Growth Bioassay*

The juvenile polychaete growth test was initiated on September 17, 2007, using the test organism (*N. arenaceodentata*) obtained from Dr. Donald Reish, California State University, Long Beach, CA. The results of the juvenile polychaete growth bioassay are presented in Tables 4-12 and 4-13. The results of the juvenile polychaete growth bioassay ranged from 0.365 to 0.574 mean individual growth (mg/individual/day) in the test sediments. One of the twenty-three test sediments failed the SQS biological interpretive criteria for the juvenile polychaete growth test. The bioassay results are displayed in Figure 4-5.

A reporting correction and a deviation from the PSEP testing protocol occurred for the juvenile polychaete bioassay. During the QA review of the bioassay data in the initial biological laboratory report the mean individual growth rate (MIG) test results were low. Upon notification, the biological laboratory discovered that the wrong bench sheets had been used for recording the final polychaete weights. Apparently at completion of the 20-day exposure period, a lab technician initially weighed the wrong set of pans for weighing the organisms. The problem was corrected at the time and the proper weigh pans were tared and used for the drying of the test organisms. However, at completion of the drying process, the wrong bench sheets were used to record the final weights of the test organisms. This occurred because two sets of pans had been prepared, and the total dry weight with organisms had been recorded on the data sheet containing the pan weights that were not used. The correct tare weights were confirmed by removing the organisms from the pans, which were then reweighed and compared to weights on the correct datasheet. The total weights were then transcribed onto the correct datasheet, and the growth values recalculated for each replicate. The laboratory had to revise the biological laboratory report with the recalculated MIG test results using the appropriate bench sheets.

A deviation from protocol also occurred in relation to the drying of the test organisms. The length of time weigh pans containing organisms dried in the oven exceeded the method requirement of 24 hours. The organisms were placed in the oven immediately after the test ended on September 13, then weighed on September 18, and checked again on September 24. The longer than 24-hour drying time at 60°C is not likely to have altered dry weights over the relatively short amount of time. The oven temperature on September 24 when weigh pans were removed from the oven was recorded as 72°C. The daily temperature logbook for that time period indicates that the oven was working properly and that temperatures were no more than 6°C of the target temperature. Despite these protocol deviations, the juvenile polychaete growth results as reported herein are considered usable for the purposes of this investigation.

Table 4–12. Juvenile Polychaete Growth Bioassay (*N. arenaceodentata*) Results and Evaluation Guidelines

Sample ID	MIG [1]	Mean MIG[2]	Reference Sediment[3]	Comparison to Reference[4]			CSL
				MIG_T/MIG_R	MIG_T vs MIG_R SD; $p = 0.05$: significant?; (test)	=	MIG_T vs MIG_R SD ($p = 0.05$); $MIG_T/MIG_R < 0.50$
						Pass/ Fail	Pass/ Fail
Control	0.621 0.586 0.404 0.478 0.406	0.499 ± 0.101	n/a	n/a	n/a	n/a	n/a
Reference CR02	0.395 0.603 0.456 0.492 0.553	0.500 ± 0.081	n/a	n/a	n/a	n/a	n/a
Reference MSMP-43	0.450 0.435 0.462 0.590 0.491	0.486 ± 0.062	n/a	n/a	n/a	n/a	n/a
Reference CR23	0.679 0.522 0.507 0.748 0.349	0.561 ± 0.157	n/a	n/a	n/a	n/a	n/a
RA2B-1	0.409 0.841 0.438 0.332 0.419	0.488 ± 0.202	MSMP-43	1.00	No (Mann-Whitney)	Pass	Pass
RA4-2	0.331 0.584 0.342 0.758 0.304	0.464 ± 0.199	MSMP-43	0.95	No (t-test)	Pass	Pass
RA4-3	0.374 0.282 0.365 0.463 0.379	0.373 ± 0.064	MSMP-43	0.77	Yes (t-test)	Pass	Pass
RA4-6	0.489 0.475 0.477 0.319 0.544	0.461 ± 0.084	MSMP-43	0.95	No (t-test)	Pass	Pass

Sample ID	MIG [1]	Mean MIG[2]	Reference Sediment[3]	Comparison to Reference[4]			CSL
				MIG_T/MIG_R	MIG_T vs MIG_R SD; p = 0.05: significant?; (test)	=	MIG_T vs MIG_R SD (p = 0.05); $MIG_T/MIG_R < 0.50$
						Pass/ Fail	Pass/ Fail
RA4-9	0.375 0.624 0.453 0.443 0.291	0.437 ± 0.123	MSMP-43	0.90	No (t-test)	Pass	Pass
RA4-10	0.353 0.272 0.289 0.452 0.460	0.365 ± 0.88	MSMP-43	0.75	Yes (t-test)	Pass	Pass
RA5-1	0.479 0.419 0.570 0.650 0.453	0.514 ± 0.094	CR-23	0.92	No (t-test)	Pass	Pass
RA5-2	0.422 0.562 0.384 0.320 0.354	0.409 ± 0.094	MSMP-43	0.84	No (t-test)	Pass	Pass
RA5-3	0.352 0.355 0.400 0.405 0.369	0.376 ± 0.025	CR-23	0.67	Yes (t-test)	Fail	Pass
RA5-4	0.353 0.334 0.401 0.276 0.786	0.430 ± 0.204	MSMP-43	0.88	No (Mann-Whitney)	Pass	Pass
RA5-5	0.539 0.145 0.288 0.229 0.537	0.348 ± 0.181	MSMP-43	0.72	No (t-test)	Pass	Pass
RA5-6	0.285 0.431 0.508 0.506 0.421	0.430 ± 0.091	MSMP-43	0.88	No (t-test)	Pass	Pass
RA5-7	0.377 0.398 0.516 0.549 0.534	0.475 ± 0.081	CR-23	0.85	No (t-test)	Pass	Pass

Sample ID	MIG [1]	Mean MIG[2]	Reference Sediment[3]	Comparison to Reference[4]			CSL
				MIG_T/MIG_R	MIG_T vs MIG_R SD; p = 0.05: significant?; (test)	=	MIG_T vs MIG_R SD (p = 0.05); MIG_T/MIG_R < 0.50
						Pass/ Fail	Pass/ Fail
RA5-8	0.380 0.596 0.693 0.329 0.467	0.493 ± 0.151	MSMP-43	1.01	No (t-test)	Pass	Pass
RA5-9	0.431 0.440 0.537 0.542 0.411	0.472 ± 0.062	MSMP-43	0.97	No (t-test)	Pass	Pass
RA5-10	0.439 0.469 0.643 0.586 0.331	0.494 ± 0.123	MSMP-43	1.02	No (t-test)	Pass	Pass
RA5-11	0.374 0.481 0.375 0.479 0.674	0.477 ± 0.122	MSMP-43	0.98	No (t-test)	Pass	Pass
RA5-12	0.352 0.443 0.688 0.766 0.381	0.526 ± 0.189	MSMP-43	1.08	No (t-test)	Pass	Pass
RA5-13	0.520 0.444 0.421 0.398 0.638	0.484 ± 0.098	CR-23	0.86	No (t-test)	Pass	Pass
RA5-14A	0.565 0.410 0.293 0.353 0.434	0.411 ± 0.102	CR-23	0.73	No (t-test)	Pass	Pass
RA5-15	0.384 0.402 0.382 0.361 0.300	0.366 ± 0.039	MSMP-43	0.75	Yes (t-test)	Pass	Pass
RA5-20	0.253 0.506 0.318 0.375 0.508	0.392 ± 0.114	MSMP-43	0.81	No (t-test)	Pass	Pass

Sample ID	MIG [1]	Mean MIG[2]	Reference Sediment[3]	Comparison to Reference[4]			CSL
				MIG_T/MIG_R	MIG_T vs MIG_R SD; $p = 0.05$: significant?; (test)	=	MIG_T vs MIG_R SD ($p = 0.05$); $MIG_T/MIG_R < 0.50$
						Pass/ Fail	Pass/ Fail
RA5-21	0.632 0.482 0.657 0.580 0.520	0.574 ± 0.074	MSMP-43	1.18	No (t-test)	Pass	Pass

Notes:
MIG = mean individual growth rate (mg/individual/day)
SD = statistically different
SQS = sediment quality standards
CSL = cleanup screening level
n/a = not applicable
Subscripts: R = reference; T = test sediment
[1] Mean individual growth per replicate (mg/individual/day).
[2] Mean individual growth ± standard deviation for sample (mg/individual/day).
[3] Reference sediment used for comparison.
[4] Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All juvenile polychaete growth data were log10 transformed for statistical analysis.

Table 4–13. Juvenile Polychaete Growth Bioassay (*N. arenaceodentata*) Results Compared to Pooled Reference

Sample ID	MIG [1]	Mean MIG[2]	Reference Sediment[3]	Comparison to Reference[4]			CSL
				MIG_T/MIG_R	MIG_T vs MIG_R SD; p = 0.05: significant?; (test)	=	MIG_T vs MIG_R SD (p = 0.05); $MIG_T/MIG_R < 0.50$
						Pass/ Fail	Pass/ Fail
Pooled Reference (MSMP-43 + CR-23)	0.450 0.435 0.462 0.590 0.491 0.679 0.522 0.507 0.748 0.349	0.523 ±0.119	n/a	n/a	n/a	n/a	n/a
RA5-9	0.431 0.440 0.537 0.542 0.411	0.472 ± 0.062	Pooled	0.90	No (t-test)	Pass	Pass
RA5-13	0.520 0.444 0.421 0.398 0.638	0.484 ± 0.098	Pooled	0.93	No (t-test)	Pass	Pass
RA5-14A	0.565 0.410 0.293 0.353 0.434	0.411 ± 0.102	Pooled	0.78	Yes (t-test)	Pass	Pass
RA5-15	0.384 0.402 0.382 0.361 0.300	0.366 ± 0.039	Pooled	0.70	Yes (t-test)	Pass	Pass
RA5-20	0.253 0.506 0.318 0.375 0.508	0.392 ± 0.114	Pooled	0.75	Yes (t-test)	Pass	Pass

Notes: MIG = mean individual growth rate (mg/individual/day); SD = statistically different; n/a = not applicable
SQS = sediment quality standards; CSL = cleanup screening level; Subscripts: R = reference; T = test sediment

1 Mean individual growth per replicate (mg/individual/day).

2 Mean individual growth ± standard deviation for sample (mg/individual/day).

3 Reference sediment used for comparison.

4 Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program; Beta v4.1). All juvenile polychaete growth data were log10 transformed for statistical analysis.

4.3.7 Summary of Bioassay Results

A summary of the results for the suite of three bioassays is presented in Table 4-14 and displayed in Figure 4-5. If all three bioassays pass the SMS biological interpretive criteria, the location is considered to have passed the SMS standards. If one of three bioassays fails the SQS biological interpretive criteria, the location is considered to have failed SMS SQS criteria. If two or more bioassays fail the SQS biological interpretive criteria or one or more bioassays fail the CSL biological interpretive criteria, the location is considered to have failed the SMS CSL criteria.

The five locations (RA5-9, RA5-13, RA5-14A, RA5-15, and RA5-20) that were not within 20 percent fines of a reference sediment were compared to a pooled reference. The pooled reference should be considered the more accurate comparison since the percent fines of the test sediment was between the range of percent fines in the two reference samples pooled. Of the five samples compared to a pooled reference, three resulted in a different interpretation than the comparison to the single reference. The sample RA5-14A is a 'pass' compared to single reference and 'fails SQS' compared to the pooled reference for the larval development bioassay. The sample RA5-15 'fails CSL' compared to a single reference and 'fails SQS' compared to the pooled reference for the larval development bioassay. The sample RA5-20 'fails SQS compared to a single reference and is a 'pass' compared to the pooled reference for the larval development bioassay. As a result of the biological testing, 6 locations passed the SMS criteria, 17 locations failed the SMS SQS criteria, and no locations failed the SMS CSL criteria.

Overall the results of the larval test are considered inconclusive due to the lack of corroborating evidence in the chemistry and other bioassay results, the poor gamete quality observed by the laboratory, and the low initial stocking density of the larval test.

Table 4–14. Summary of Bioassay Results

Station ID	Amphipod Mortality	Larval Development	Juvenile Polychaete Growth	SMS Results[1]
RA2B-1	Pass	**Fail SQS**	Pass	**Fail SQS**
RA4-2	Pass	**Fail SQS**	Pass	**Fail SQS**
RA4-3	Pass	**Fail SQS**	Pass	**Fail SQS**
RA4-6	Pass	**Fail SQS**	Pass	**Fail SQS**
RA4-9	Pass	**Fail SQS**	Pass	**Fail SQS**
RA4-10	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-1	Pass	Pass	Pass	Pass
RA5-2	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-3	Pass	Pass	**Fail SQS**	**Fail SQS**
RA5-4	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-5	Pass	Pass	Pass	Pass
RA5-6	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-7	Pass	Pass	Pass	Pass
RA5-8	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-9	Pass[2]	Pass[2]	Pass[2]	Pass[2]
RA5-10	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-11	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-12	Pass	**Fail SQS**	Pass	**Fail SQS**
RA5-13	Pass[2]	Pass[2]	Pass[2]	Pass[2]
RA5-14A	Pass[2]	**Fail SQS[3]**	Pass[2]	**Fail SQS**
RA5-15	Pass	**Fail SQS[3]**	Pass	**Fail SQS**
RA5-20	Pass	**Pass[3]**	Pass	**Pass[3]**
RA5-21	Pass	**Fail SQS**	Pass	**Fails SQS**

Notes:

[1] The SMS results provide a summary of the results for the suite of three bioassays. 'Pass' indicates all three bioassays pass the SMS biological interpretive criteria. If one of three bioassays fails the SQS biological interpretive criteria, the location fails SQS. If two or more bioassays fail the SQS biological interpretive criteria or one or more bioassays fail the CSL biological interpretive criteria, the locations fail CSL.

[2] The result is for the pooled reference comparison and is in agreement with the comparison to a single reference.

[3] The result is for the pooled reference sediment and is not in agreement with the comparison to a single reference. The pooled reference should be considered the more accurate comparison since the percent fines test sediment was between the range of percent fines in the pooled reference samples.

.

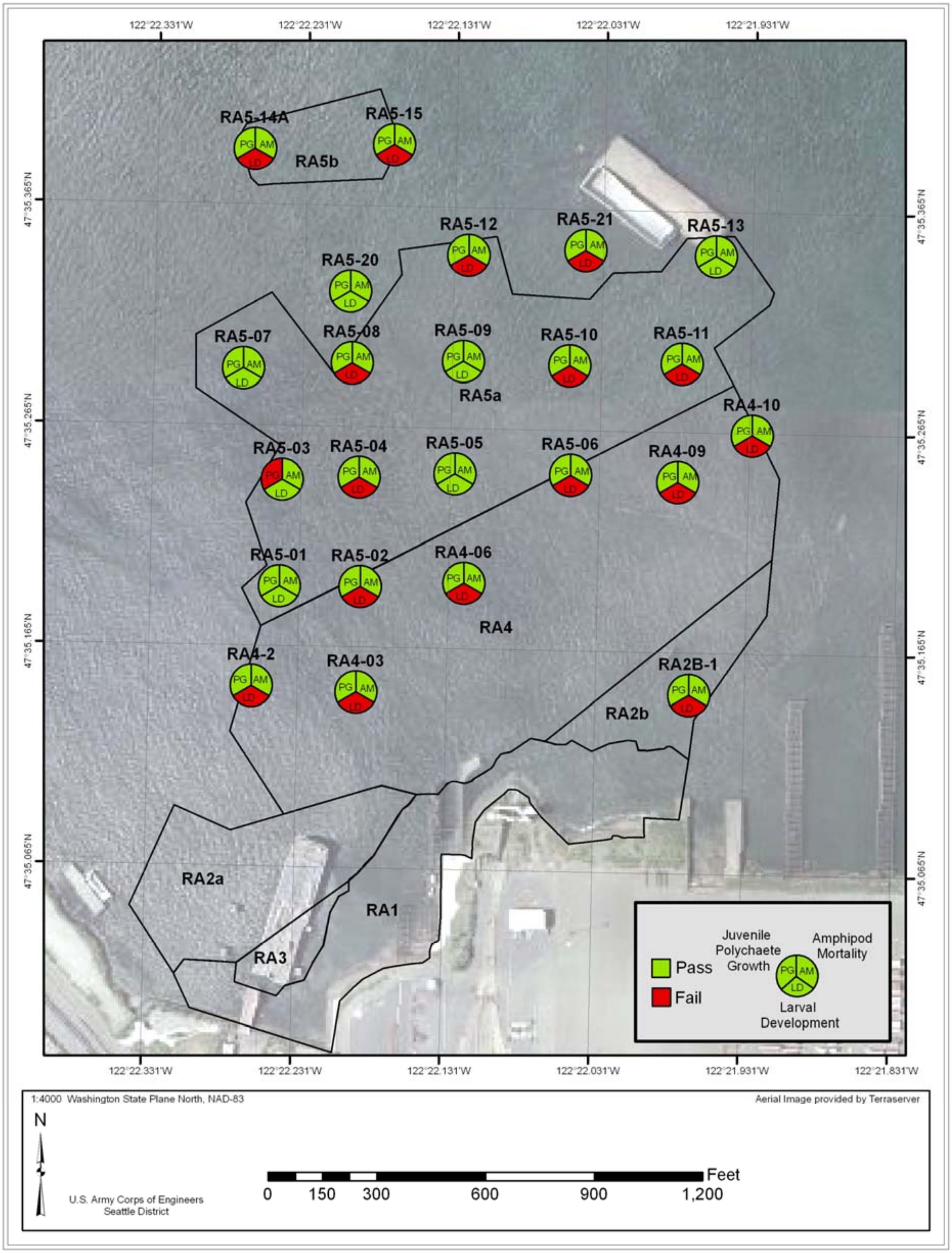


Figure 4–5. Bioassay Results for the 2007 PSR Monitoring

4.4 Bathymetric Survey

The bathymetric survey was conducted between August 4 and August 9, 2007. During survey operations, each of the 56 primary north-south survey lanes, as well as the supplemented series of cross lanes, were occupied. However, small sections of several lanes were inaccessible due to the presence of barges moored within the survey boundaries (Figure 4-6).

The bathymetric and topographic data collected over the PSR survey area indicated a range of elevations from 22 feet above the MLLW datum point to water depths of 280 feet below MLLW (Figure 4-7). The areas above the MLLW line include the beach face within RA1, and are represented as a moderately sloping transition area. The range of elevations within RA1 extends from 15 feet above MLLW, gradually sloping below MLLW mark to water depths of 20 feet at the boundary between RA2a, RA2b, and RA4. As the survey extended further offshore, RA2a and RA2b exhibited the least amount of seafloor relief and slope, as water depths increased from approximately 20 to 65 feet in RA2a and from 20 to 40 feet below MLLW in RA2b. The smallest of the remediation areas, RA3 displayed a range of water depths from 15 to 35 feet below MLLW and more relief than either RA2a and RA2b.

The greatest range in water depths of 30 to 150 feet below MLLW was observed in RA4. This area displayed the steepest bottom slopes encountered within the survey area, as indicated in the number of tightly spaced contour lines. The 120-foot change in water depth across the approximately 600-foot wide area of seafloor equates to a 20 percent grade (10° slope) along the bottom. This is relatively steep grade in a subaqueous environment, suggesting the seafloor is composed of a consolidated material with an ability to maintain a high angle of repose.

Remedial Areas 5a and 5b extend out towards the center of Elliott Bay and exhibit the deepest depths within the survey boundary. Water depths within RA5a ranged from 145 to 215 feet below MLLW, while water depths at RA5b ranged from 230 to 235 feet below MLLW. The only large feature evident in the bathymetric data was a small mound on the western boundary of RA5a.

4.5 Intertidal Beach Walk/Topographic Survey

A total of 18 intertidal beach walk transects (shore-normal) were completed along the shoreward extents of RA1 on August 9 during a period of lower low tide ("minus tide"; Figure 4-8). The transects began in the southwest corner of the survey area in proximity to the Pier 2 barge mooring facility and continued to the east and northeast through Pier 3 Park and eventually to the PSR waterfront adjacent to Pier 4. The linear distance covered by each beach walk transect ranged from 30 to 250 feet and was directly associated with the overall slope and composition of the shoreline being mapped. Digital photographs were obtained from each transect from the water line and the apparent higher high water line (Appendix F).

Transect Lines 1, 2, 3, 5, and 6 began on an engineered rocky riprap shoreline revetment in close proximity to Pier 2. The engineered 2H:1V riprap revetment extends from approximately +5 feet MLLW to -40 feet MLLW west of Pier 2 and is keyed in with a buried toe. The revetment extends from +5 feet MLLW to about -20 feet MLLW east of Pier 2 and is also keyed in with a buried toe. The upland portions of the transect displayed elevations ranging between 10 to 16 feet above MLLW and continued down a steep grade to a relatively flat cobble/pea gravel beach ending just above the low tide line (Figures 4-9 and 4-10). Comparing transects 1, 2 and 6 from the recent survey to the Post-Construction survey indicate there has been movement of the habitat fill placed on top of the riprap revetment (approximately 1- to 2-foot elevation change) near the intertidal area where the 10-foot bench was constructed. However, a net accretion of sediment above mean high water suggests that this material has been moved onshore via wave action. In transects 3 and 5, which are directly adjacent to Pier 2, there is a net lowering of the profile, suggesting the habitat and gravel material placed on top of the riprap has been transported alongshore both west and east of the pier. This may be a result of propeller wash from tugs positioning barges and the concave geometry of the shoreline.

Transects 9 to 14 established between Pier 2 and Pier 3 show a variety of shoreline slopes and beach sediments. The low tide conditions allowed this transect to begin at approximately 4 feet above MLLW (7.3 feet below the MHHW) and continue 120 feet along a moderate 1.5°slope (3 percent grade) to the low tide line (Figure 11). The exposed beach face was primarily composed of pea gravel and cobble before transitioning to larger cobble and boulders at the low tide line. At, transect 9 the engineered riprap revetment ties directly into shoreline armor existing prior to construction and shows overall little change except for some apparent loss of material on the bench between elevation 0 and 5 feet MLLW. It is likely that the erosion here is a result of the redistribution of habitat mix and/or settlement of the riprap. Transects 11 and 12 were obtained over a broad beach face in proximity of a concrete overlook deck associated with Pier 3 (Figure 4-12). Transects 11 and 12 extend across beach sediments composed of habitat and gravel mix and show a general trend of backshore berm growth above the high water line. The growth of the berm feature is supplied from sediments from the intertidal region which showed a net erosion of approximately 1 to 2 feet. Transects 13 and 14 were both established in proximity to Pier 3, and terminated at nearly the same geographic point just west of the pier structure (Figure 4-13). The beach was comprised primarily of pea gravel and cobble before transitioning to larger cobble and bolder size grains toward the end of each transect. Transect 13 and 14 located directly west of Pier 3 show net erosion that is likely an effect of longshore transport to the south due to the primary wave incidence from the north-northwest. This area shows the largest erosion of all transects monitored at approximately 3 feet.

Transects 15 and 16 were established just east of Pier 3, adjacent to the engineered riprap shoreline revetment and along a relatively small beach face (40 to 45 feet). Transects 15 and 16 began just below the MHHW mark along the riprap wall and extended 40 feet to a point just above the MLLW line (Figure 4-14). The shoreline slope at this location is consistent with a static revetment. The large difference between the recent survey and the post-construction survey at a distance of 25 feet along the profile is likely a product of the survey detail. The transect is located very close to the boundary of where riprap was placed in the intertidal region east of the pier (as shown in Figure 4-14)

Transects 18 through 22 fall within the eastern pocket beach, The subtidal portion of the cap material is composed of gravel and habitat mix classified as mildly sloping and transitions directly into the RA2b cap. This potion of the cap does not have a riprap revetment perching up the intertidal beach and therefore is inherently more stable. The intertidal beach face along Transect 18 is primarily comprised of pea gravel and cobble-sized grains, while the upland substrate is a vegetated sand/silt/clay soil mix contained by various erosion control measures displaying elevations 18 to 27 feet above MLLW. The apparent thickness of fill material along Transect 18 varies from 1 to 14 feet, with the bulk of that material existing in the intertidal zone (Figure 4-15). A sand berm approximately 2 to 3 feet high was once again detected protruding above the MHHW mark on Transect 18. Similar to several transects west of Pier 3, this deposit of sandy material is likely the result of winnowing of finer grained material in the swash zone via sorting by wave action on the beach face. This site is essentially unprotected from wind generated waves emanating from the northwest, as well as the wakes generated by passing commercial vessels. Therefore, these waves possess sufficient energy to mobilize and transport sand and pebble size grains on the beach face.

The results for Transect 19 are similar to that of Transect 18, showing elevations in the upland portion of the transect ranging from 14 to 23 feet above MLLW (Figure 4-16). The first 100 feet of this transect was defined as upland since the same vegetated sand/silt/clay soil matrix was present. At the MHHW mark, the slope of the beach was nearly flat (2° slope; 4 percent grade) inland of a sandy berm that was encountered approximately 150 feet along this transect. The slope of the beach face steepened seaward of this berm (7.5° slope; 15 percent grade) as the transect continued to an end point just below the MLLW mark (-1 feet) due to the minus tide. Analogous to much of intertidal areas within the PSR site, pea gravel and cobble sized grains dominated the exposed beach face.

Transect 20 was 120 feet long, roughly one-half the distance of Transect 19, and excluded much of the upland area. Beginning just above the MHHW mark, the profile of the intertidal zone was similar to the lower portions of Transect 19, displaying a sandy berm 2 to 3 feet high, gradually sloping to a point just above the MLLW mark (Figure 4-16).

Transects 21 and 22 were used to evaluate the profile of the beach at the easternmost section of the PSR remediation area, in proximity to a wooden bulkhead structure and pier. As anticipated, the elevations and profile of Transect 21 were comparable to Transect 20, but without the presence of a distinct berm feature at the MHHW line (Figure 4-17). The start point of this transect was at an elevation of 14 feet above MLLW, and the transect line proceeded over relatively flat terrain for approximately 30 feet before encountering the MHHW mark. At the MHHW line, the profile displayed a change in slope (6.8° slope; 13.6 percent grade), which remained consistent as the survey continued along the pea gravel and cobble beach to a point 1.5 feet above the MLLW mark.

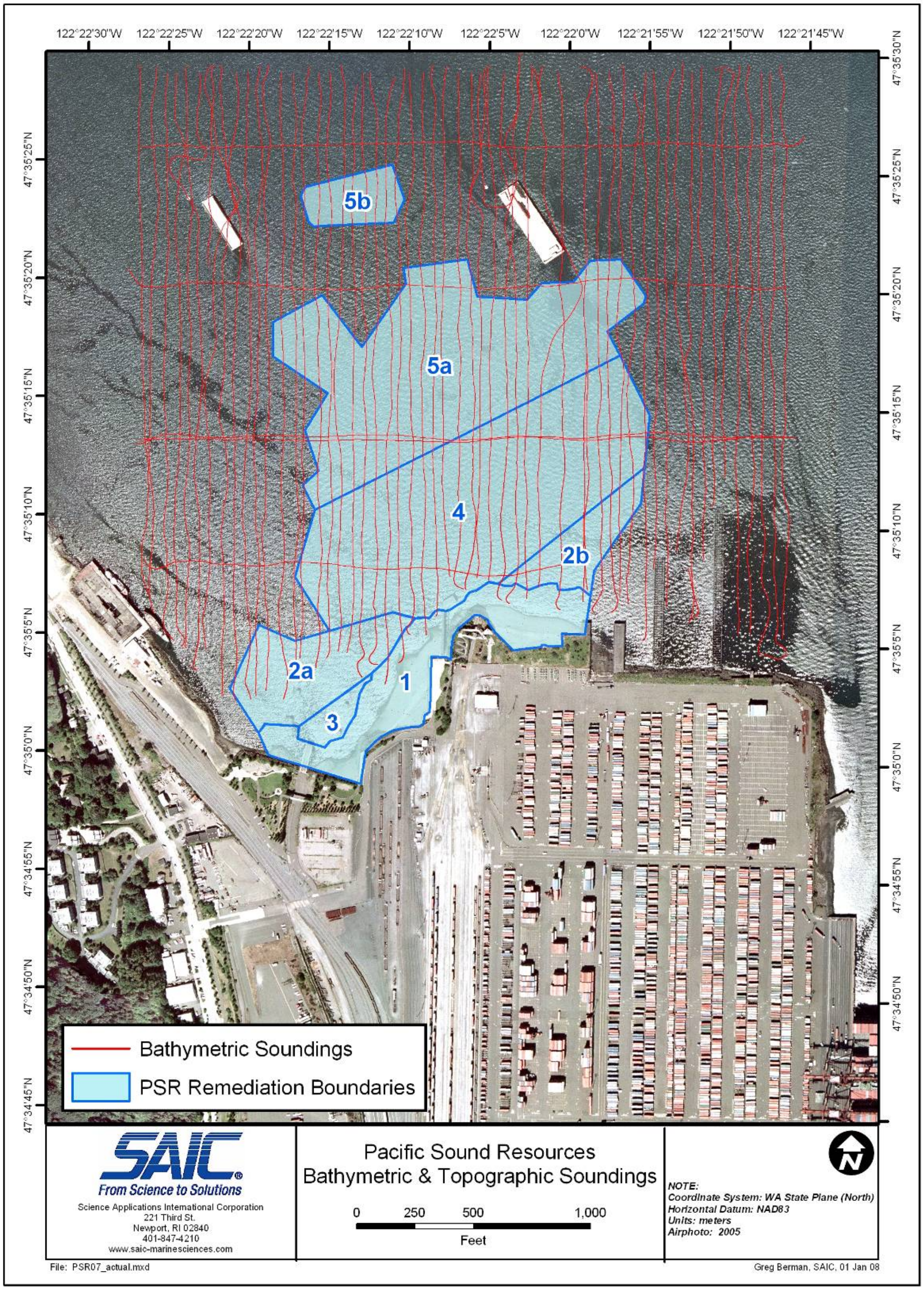


Figure 4–6. Actual Soundings Collected during the Bathymetric Survey

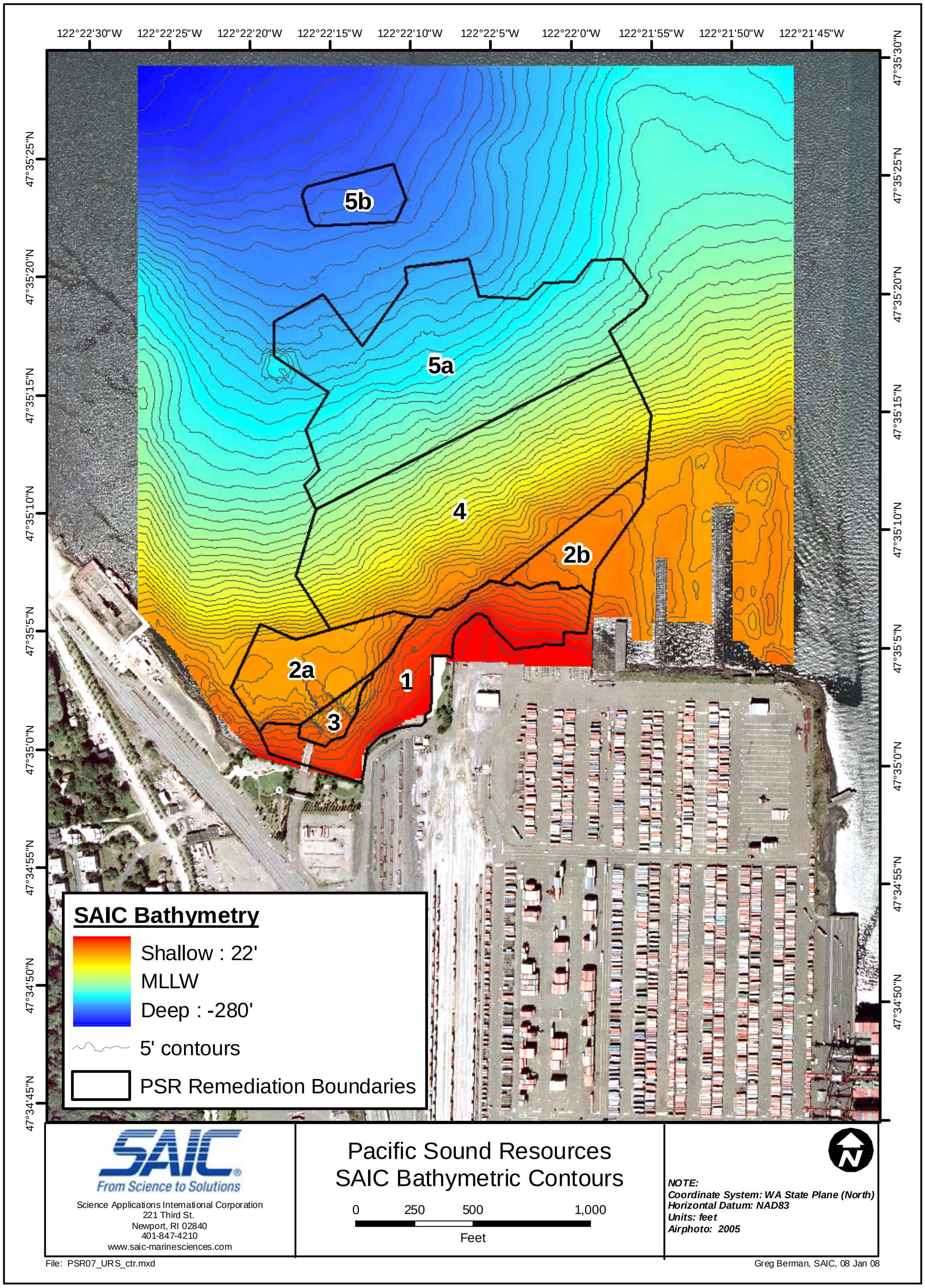


Figure 4–7. Bathymetric Data Collected over PSR Overlaid with PSR Remediation Areas

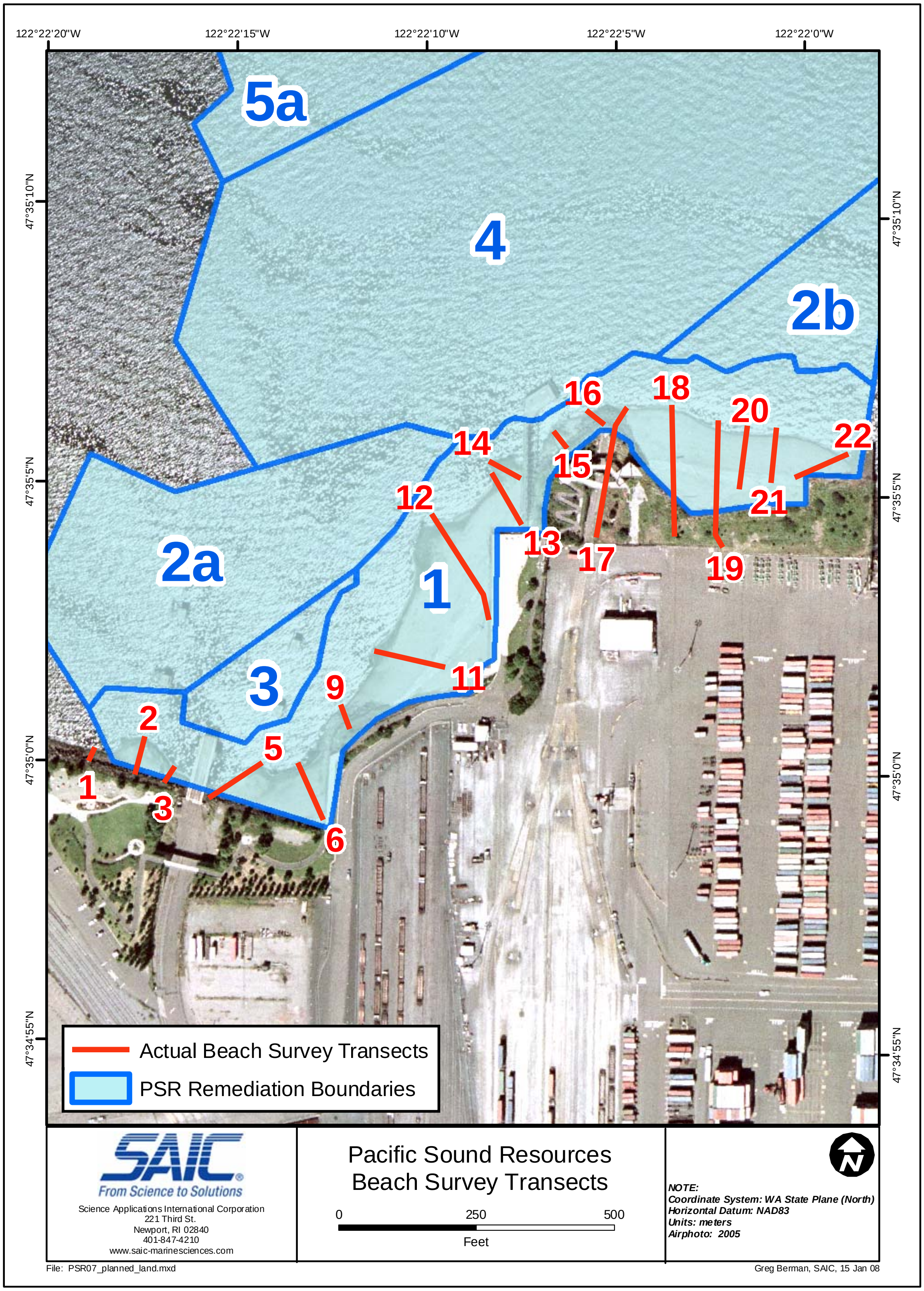
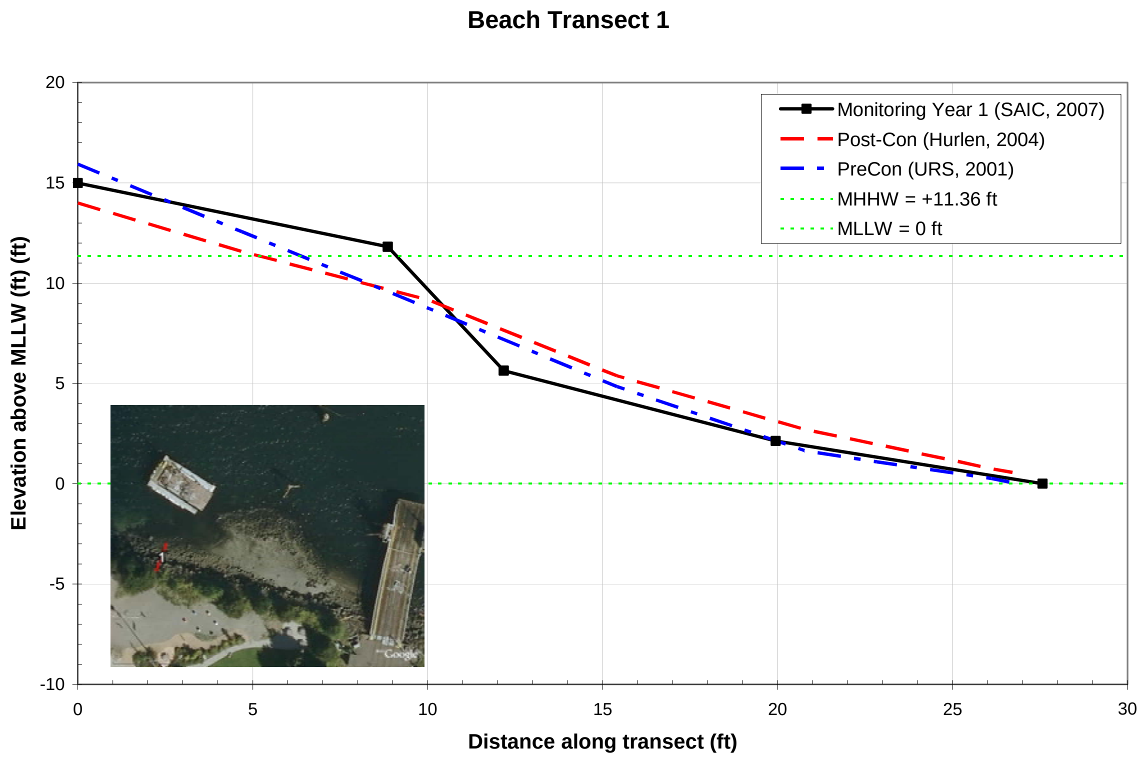


Figure 4–8. Actual Transect Lines Occupied during the Beach Walk Survey



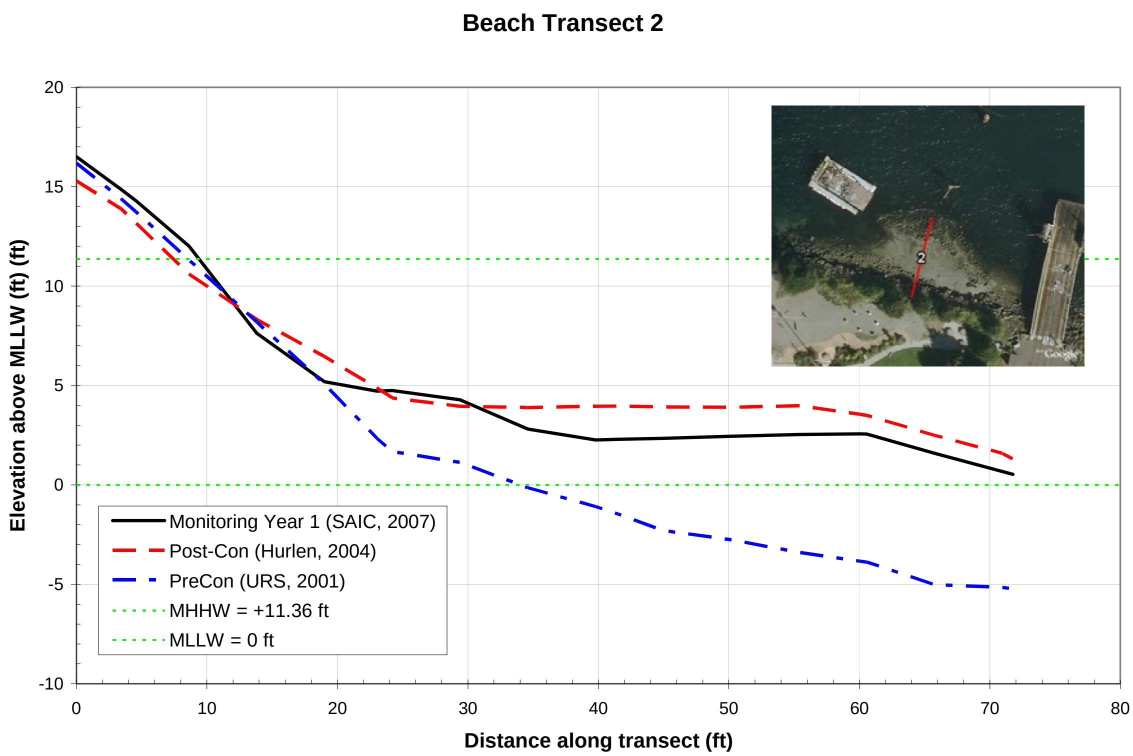
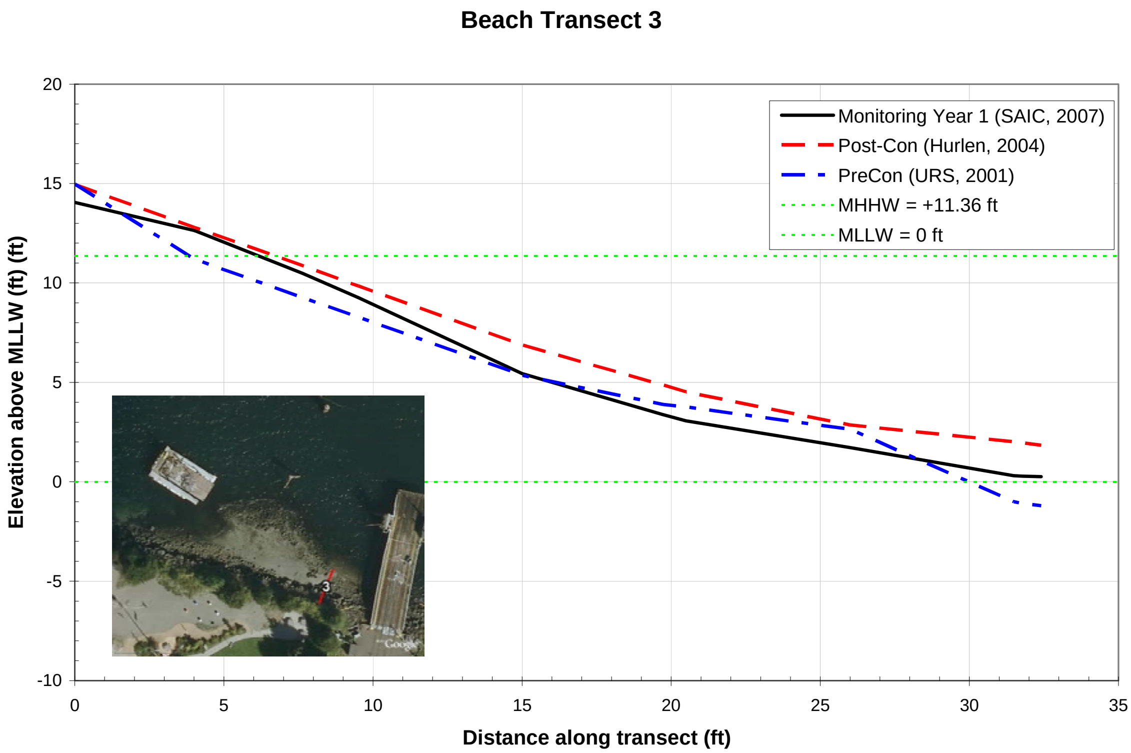


Figure 4–9. Beach Walk Cross-Section of Transects 1 and 2 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



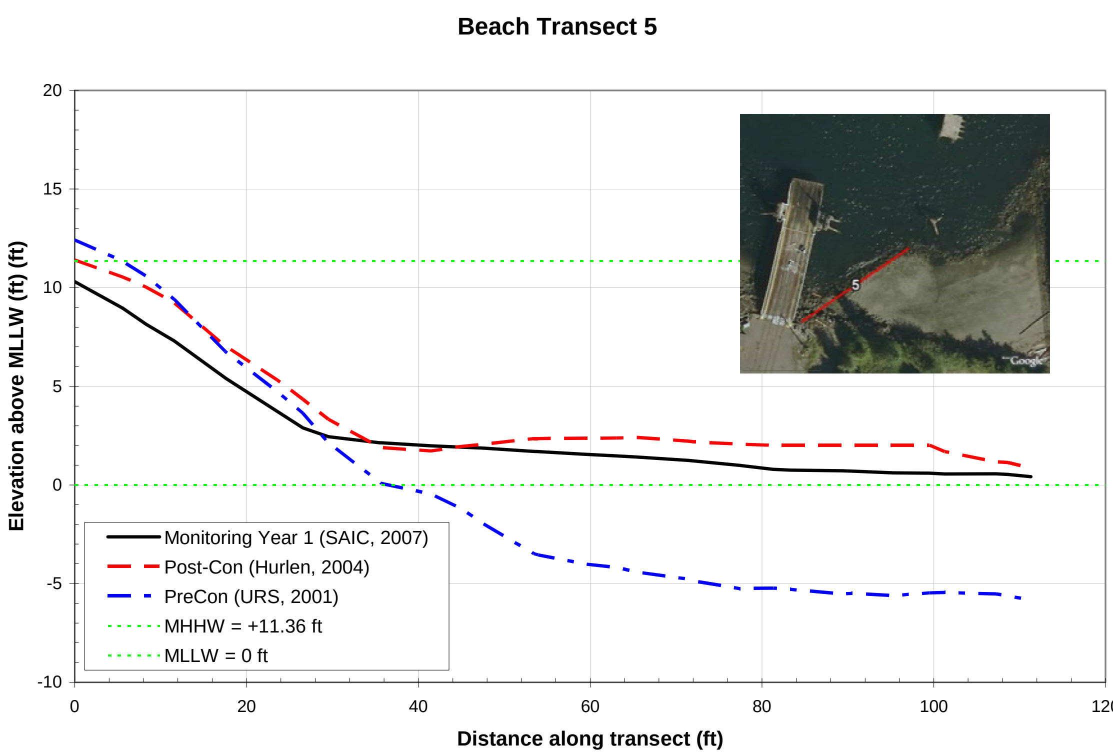
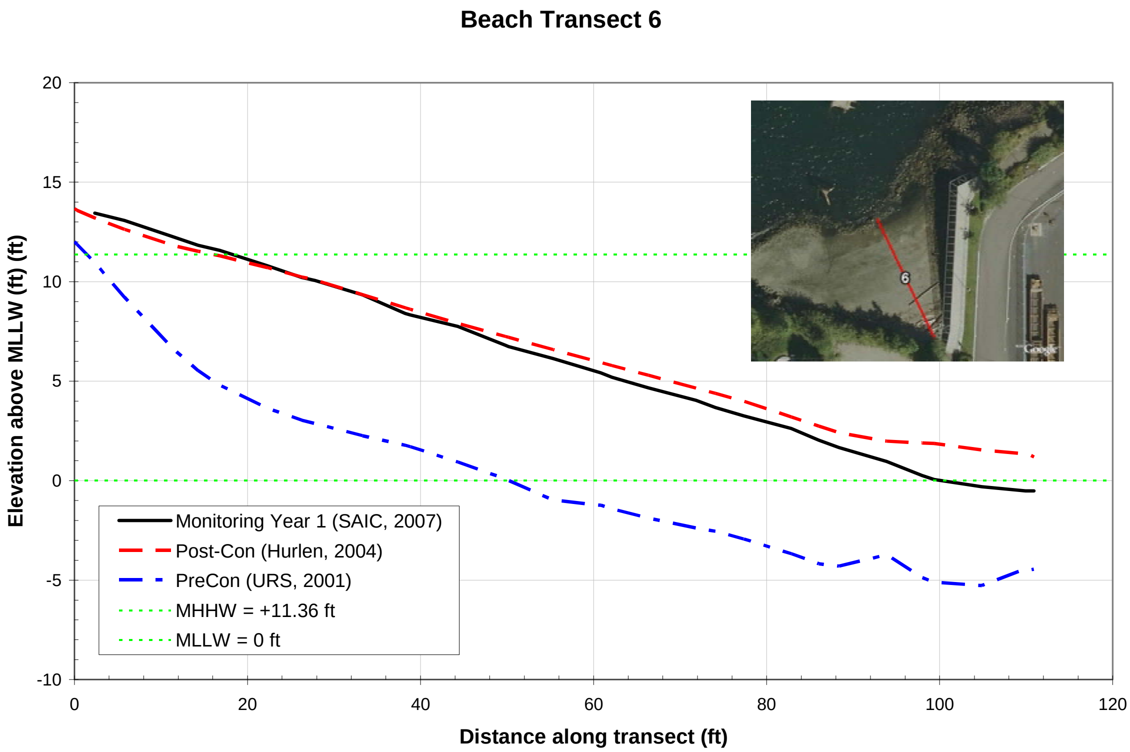


Figure 4–10. Beach Walk Cross-Section of Transects 3 and 5 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



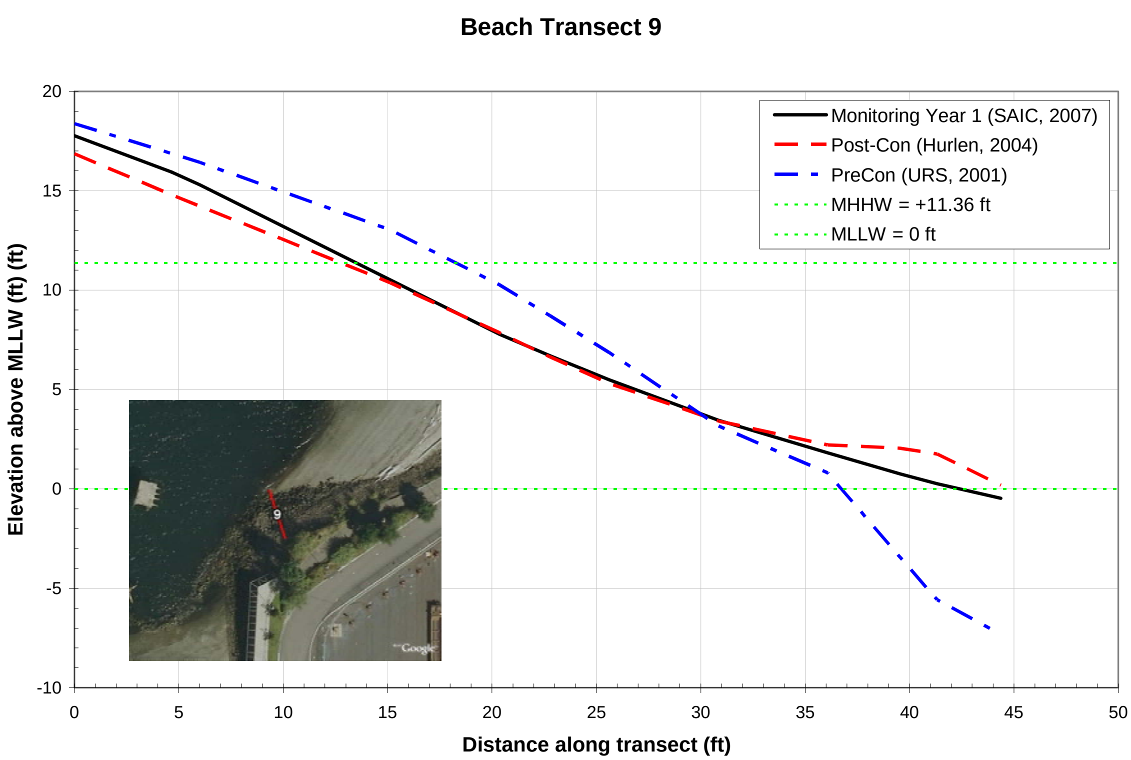
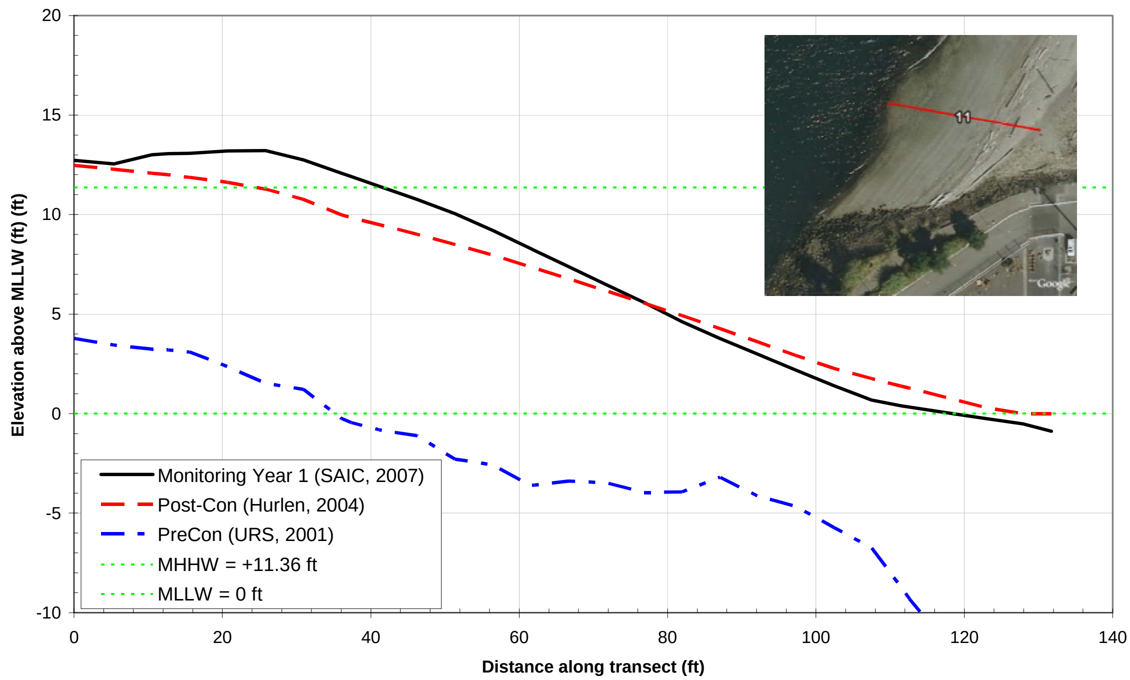


Figure 4–11. Beach Walk Cross-Section of Transects 6 and 9 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC

Beach Transect 11



Beach Transect 12

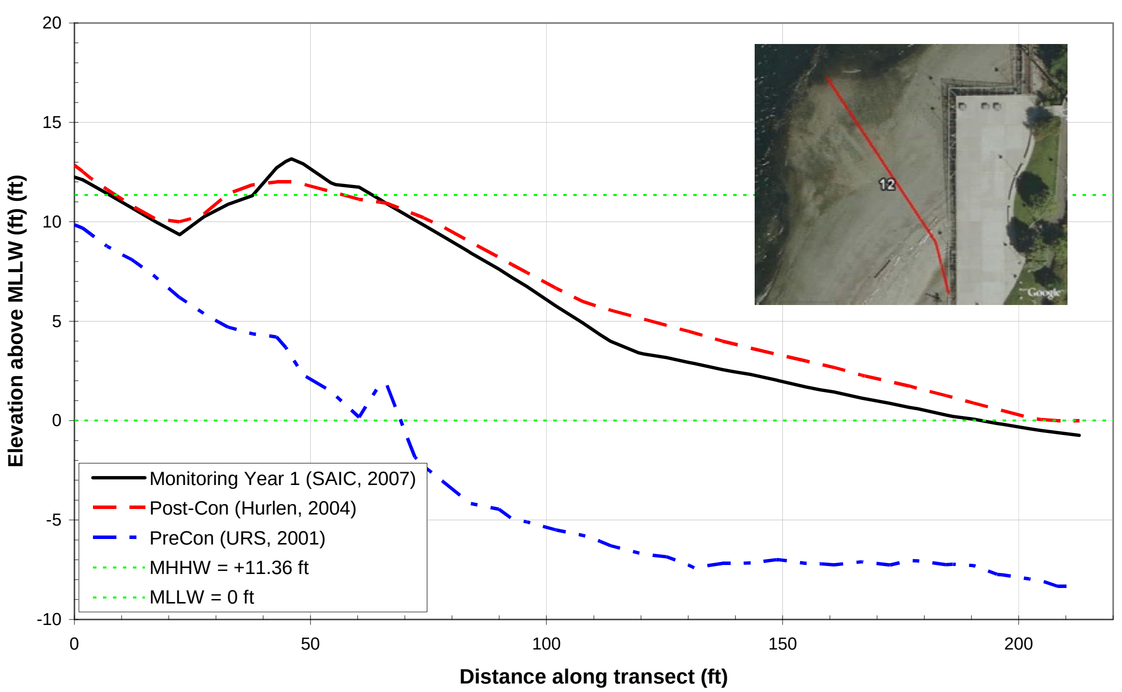
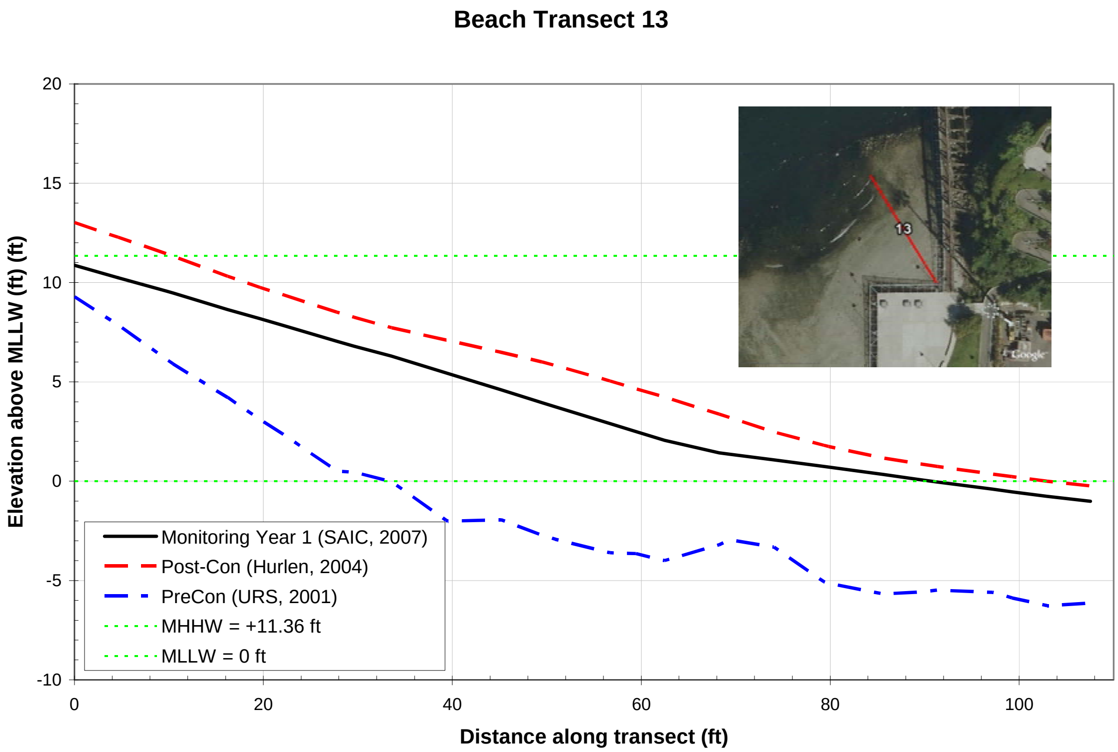


Figure 4–12. Beach Walk Cross-Section of Transects 11 and 12 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



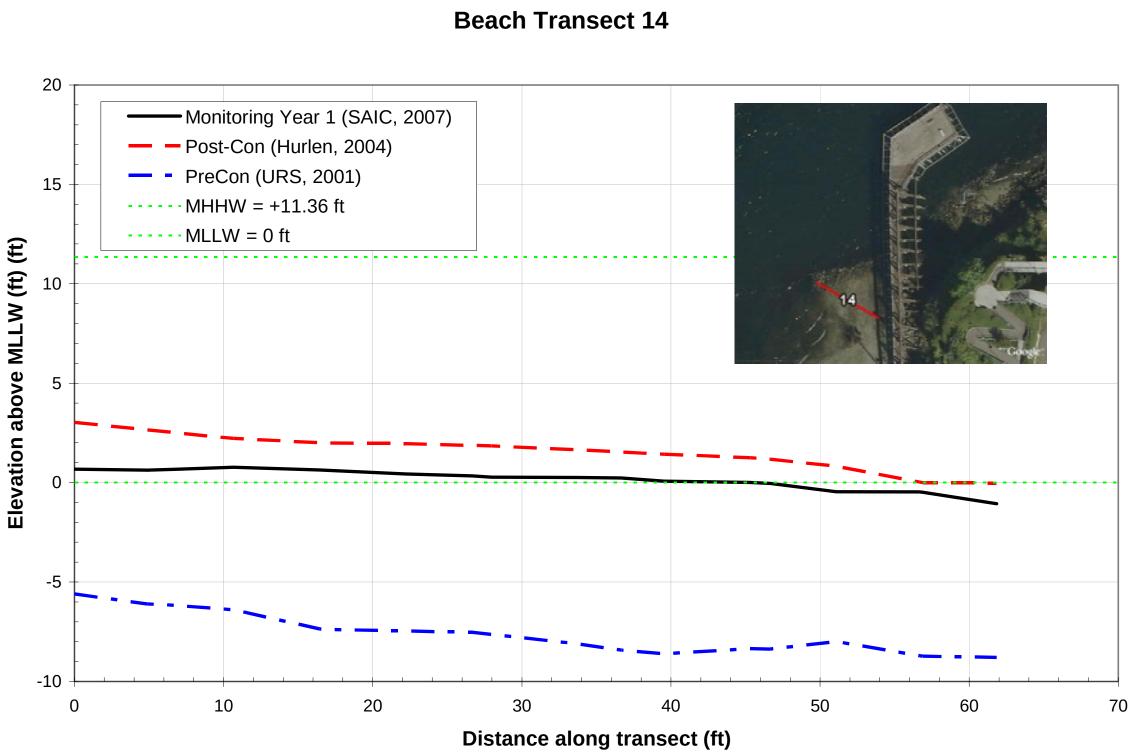
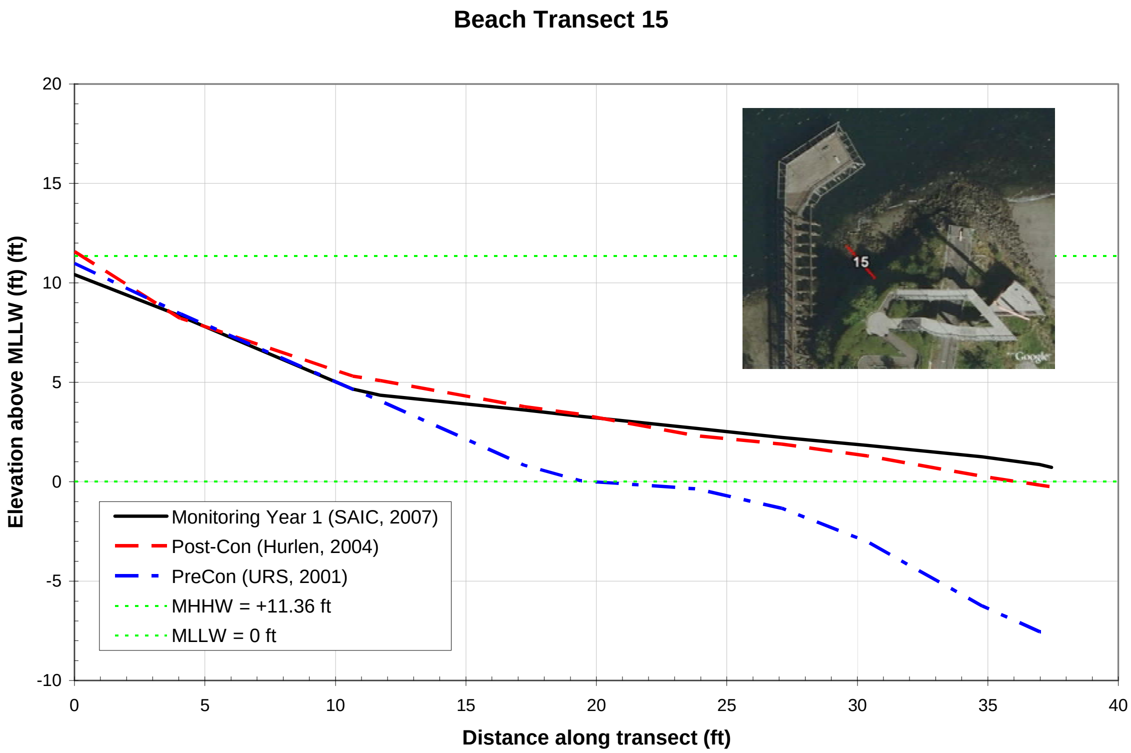


Figure 4–13. Beach Walk Cross-Section of Transects 13 and 14 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



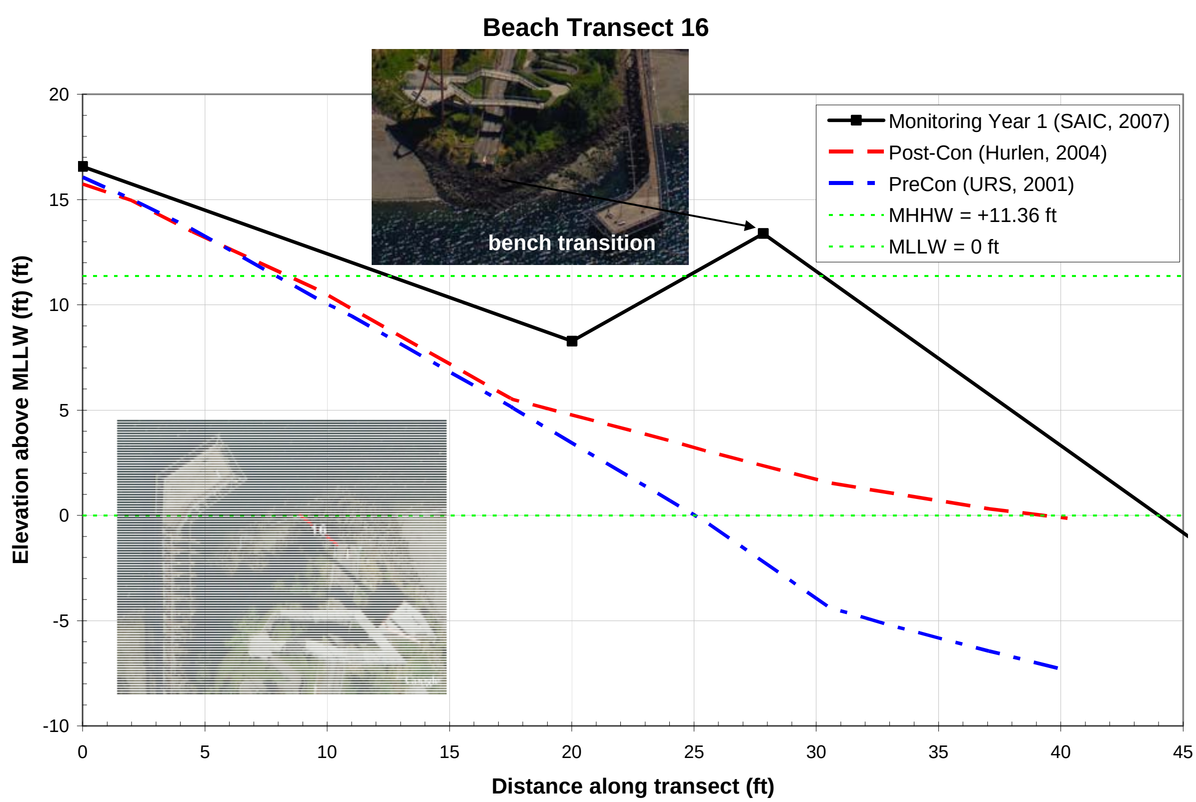
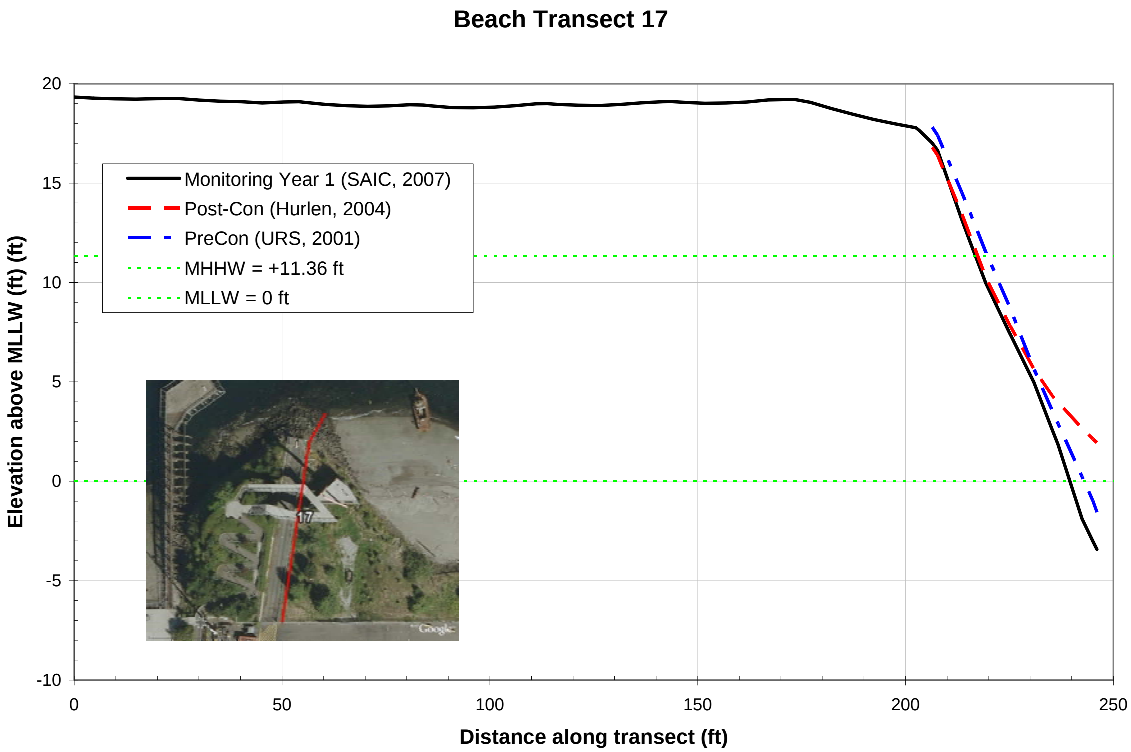


Figure 4–14. Beach Walk Cross-Section of Transects 15 and 16 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



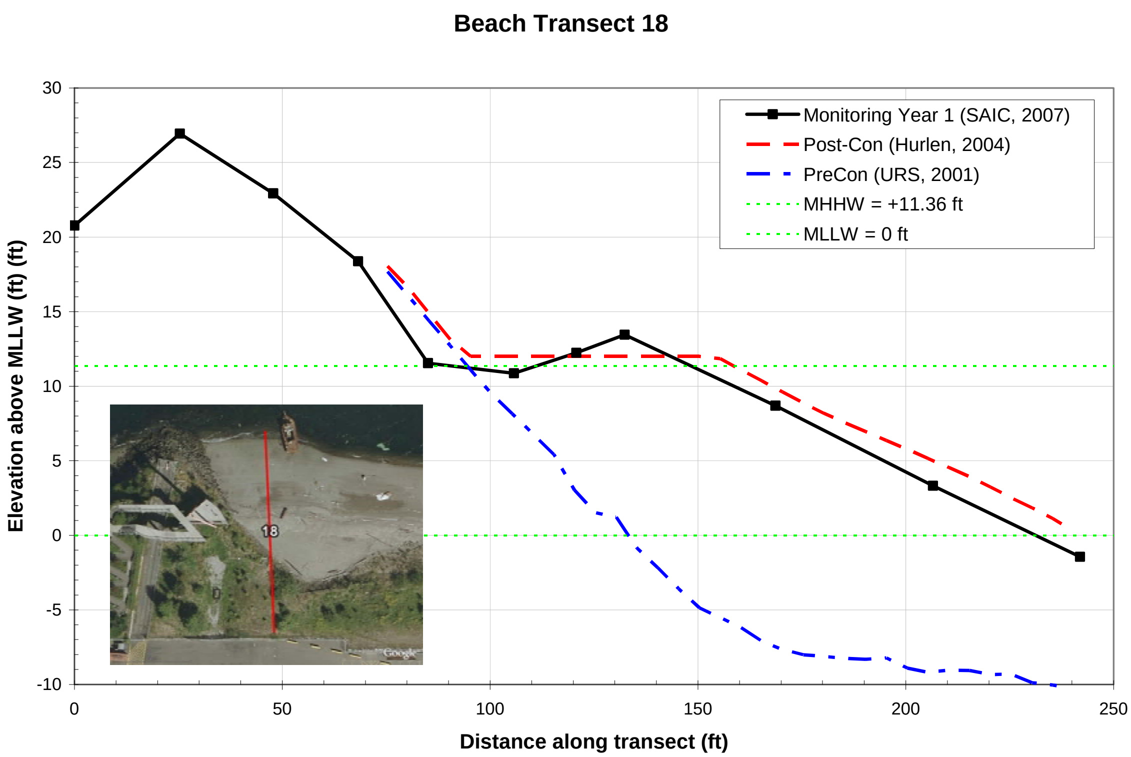
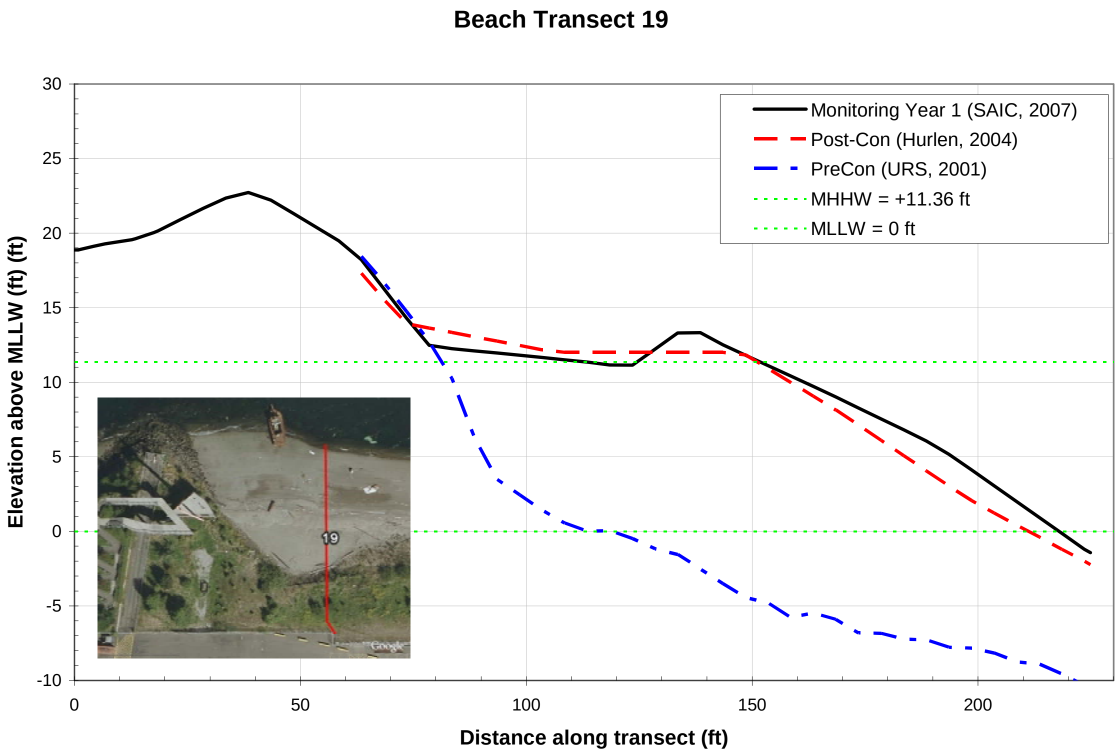


Figure 4–15. Beach Walk Cross-Section of Transects 17 and 18 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC



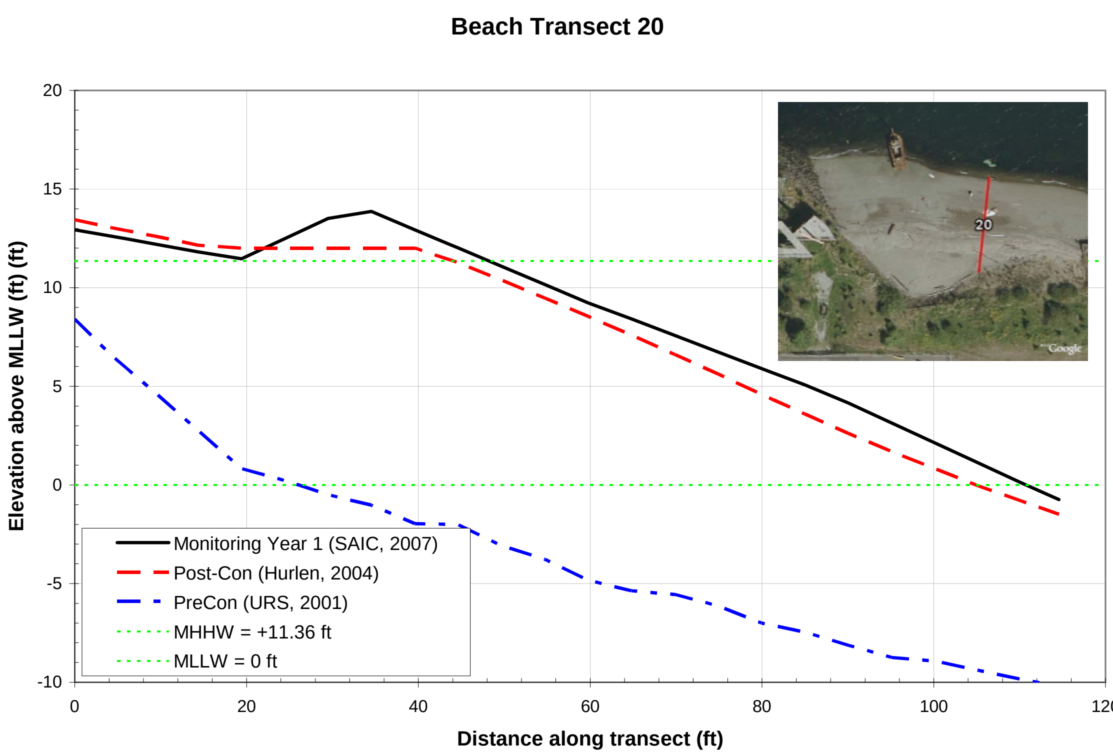
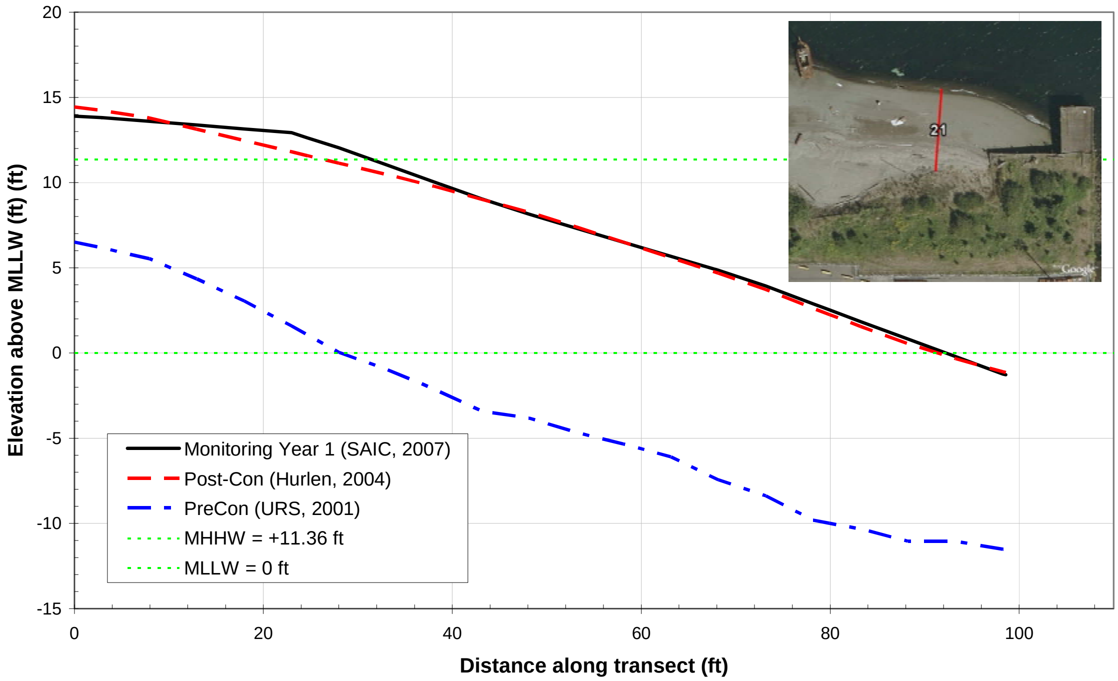


Figure 4–16. Beach Walk Cross-Section of Transects 19 and 20 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC

Beach Transect 21



Beach Transect 22

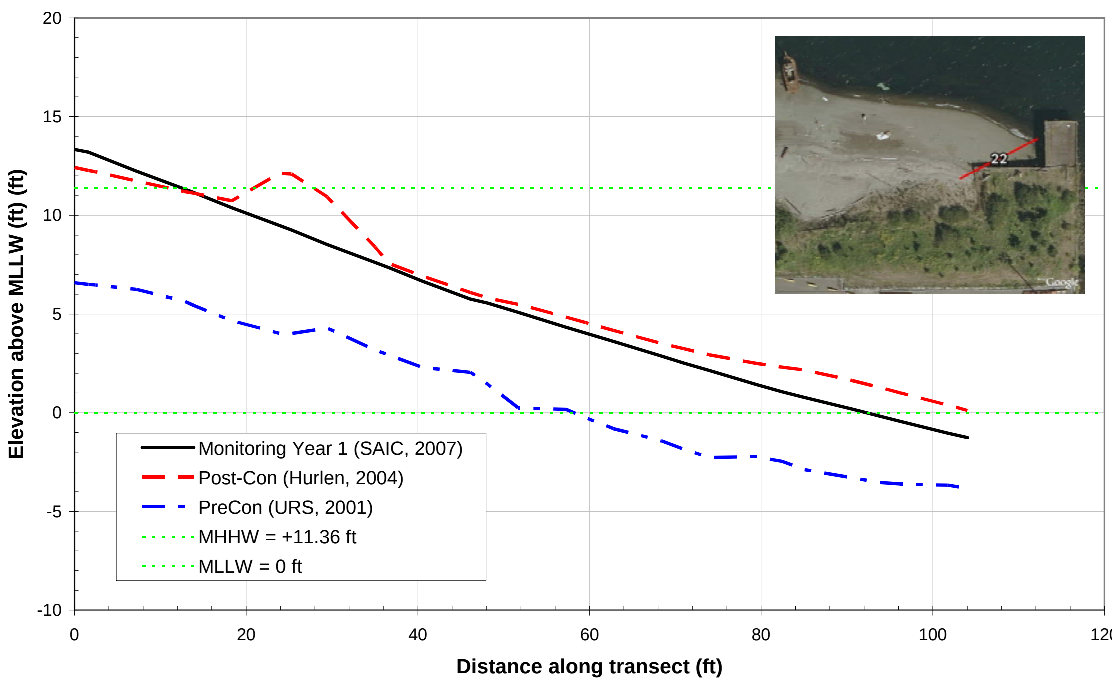


Figure 4–17. Beach Walk Cross-Section of Transects 21 and 22 of the Current Data Set and the Pre-Construction Survey Conducted by URS and Post-Construction by Hurlen/ACC

5.0 Summary

5.1 Conditions in the MSU

The current conditions of the MSU RA5, based on the results from the 16 locations monitored in 2007, are that the surface sediment meets the Washington State SMS SQS chemical criteria for sediment quality, with the exception of one sample. The duplicate sample analyzed at RA5-14A exceeded the SQS for total PCBs. However, the subsurface core collected at this location did not indicate the presence of any cap material. Therefore, it is possible the PCBs are residual contamination from the site. All other locations with chemistry exceeding the SMS numeric criteria were from outside the remediated area.

Despite meeting the SMS chemical criteria for the various RAs, the confirmatory biological tests did not meet the SQS criteria for 17 of the 23 locations tested. The larval development bioassay failed the SQS criteria at 16 locations in RA2, RA4, RA5, and RA5b. The juvenile polychaete growth bioassay failed the SQS criteria at one location in RA5. It is not evident from the chemistry data what the source is for the observed toxicity. One possibility is the presence of a contaminant that is not routinely tested for under SMS. However, it is more likely the observed toxicity was the result of a particularly sensitive test due to poor gamete quality and low stocking density in the larval development test as discussed in Section 4.3.5.

The walking beach topographic transects surveyed in the intertidal region of RA-1 indicate that the cap is physically stable. There is no indication of slope failure of the engineered riprap revetment, toe berm, or buried toe. Since the intertidal beach upland is essentially perched and held in place by this structure, a failure would result in an overly steepened beach slope near the mean lower low water line. This was not observed in the transect data collected; however additional monitoring in the subtidal areas of the cap would more effectively support this claim. Redistribution of sediments by swash zone transport has been observed in the sections of gravel/pebble beach. Transects 13 and 14 were observed to have the largest magnitude of erosion, and is speculated in part due to the fact that the shoreline is oriented along the north-south direction resulting in a high longshore transport rate to the south. In addition, sections of intertidal beach (transects 11 to 12 and 18 to 22) have developed a sand berm feature with a crest height approximately 2 to 3 feet in height above the mean higher high water line. The redistribution of sediments does not present any immediate threat to the stability of the cap, however may require periodic nourishment to ensure the cap meets other project criteria.

5.2 Comparison of Results to Expectations

The results of the 2007 monitoring event, with the exception of the biological testing, were generally as expected based on the findings of the 2006 Long Term Monitoring Report (SAIC 2006). Sediment chemistry within the remediation area remained below the SMS. Slight differences were observed in cap thickness between 2006 and 2007.

The average cap thickness for the site was approximately 11.5 inches (ranging from 2.4 to 43.3 inches) based on the eleven 2006 monitoring locations. The average cap thickness based on 16 sites in 2007 was 9.7 inches with a range of 0 to 21.3 inches. The observed cap thickness was below design specifications, which called for a minimum thickness of 27 inches. Based on the consistent variance in measurement, the monitoring data suggest high spatial variability in cap thickness across RA5. Also, the decrease in the mean cap thickness from 2005 to 2007 indicates compaction occurring as cap material settles over time.

The area-wide toxicity was not anticipated based on the chemistry results for both the 2006 and 2007 monitoring events. It is not known what the source of observed toxicity is based on the data collected for this investigation. It is possible the observed toxicity is the artifact of an overly sensitive bioassay due to the quality and density of the test larvae.

5.3 Recommended Revisions to Monitoring

The results of the PSR monitoring efforts provide key information regarding sediment cap conditions at RA5 for chemical compliance, biological compliance, and physical measures. Presently the cap is generally in compliance with the chemical testing requirements. The single location that exceeded the SQS for total PCBs was also lacking the presence of any cap material. However, the sediment cap in RA5 is not in compliance with the physical measurements requirements for cap thickness. It does appear the cap has provided an effective barrier relative to the chemical criteria.

Toxicity was observed in the larval development bioassay for 16 locations throughout the site, and for the juvenile polychaete growth bioassay for one location in RA5. The results of the larval development test are not corroborated by chemistry or the other two bioassays that were conducted. However, despite the inconclusive results of the confirmatory biological tests, biological testing is recommended for future monitoring events.

A cap recontamination investigation was not conducted as part of the 2007 monitoring event based on the following reasons:

1. The surface sediment chemistry did not exceed SMS SQS criteria where cap material was present.

2. The sediment cap was less than minimum design specifications in all 16 samples collected.

The recommendations based on the 2007 monitoring event would be to place additional cap material until design specifications are met or modified. The exceedance of both the SQS and CSL in the OSA samples may warrant further investigation to determine whether the capped area should be expanded. The failure of the confirmatory biological tests, though inconclusive indicate the need for additional confirmatory biological testing in future monitoring events. Further monitoring is recommended on an interim basis until the sediment cap is in place that meets design specifications. It does appear that the existing sediment cap is providing sufficient protection to the benthic community from a chemical standpoint.

RA1 monitoring included a walking topographic survey along designated transects. These transects extend down to approximately MLLW. However, the RA1 thick slope cap (engineered revetment) composed of riprap extends to elevations in the range of -30 to -40 feet MLLW. Attempts to continue the beach transect offshore (via marine equipment, wave runner, etc.) along this portion of cap is recommended to gain additional insight regarding the physical stability of the buried toe (transects 1 to 9) and the toe berm (transects 11 to 17). The stability of the perched beach sediments upland will directly depend on the slope stability of these areas. In addition, survey results in the area west of Pier 3 (transects 13 and 14, Figure 4-13) indicate that up to 3 feet of cap erosion has occurred. We recommend that this area be included as part of a subsequent sediment cap monitoring round to ensure that the existing cap thickness remains protective.

Future monitoring of elevation changes in RA2, RA3, RA4, and RA5 would benefit from a consistent repeatable survey plan. Future transects should not deviate more than a few feet from previous transects. Additionally, the survey density spacing between north-south transects should be equivalent to the spacing of the east-west transects to limit bias if the data is being used to construct a digital terrain model grid.

6.0 References

Anchor Environmental. 2005. Data Report, Construction and Post-Construction Monitoring of RA5 Marine Sediment Unit, Pacific Sound Resources Superfund Site. Prepared for U.S. Army Corps of Engineers, Seattle District, Seattle, WA. Prepared by Anchor Environmental, Seattle, WA. August 2005.

Ecology. 1996. Progress Re-evaluating Puget Sound Apparent Effects Thresholds (AETS) Values. 1994 Amphipod and Echinoderm Larval AETS. Draft Report. Prepared by the Washington Department of Ecology for the Puget Sound Dredged Disposal Agencies (PSDDA). April 1996.

Ecology. 2003. Sediment Sampling and Analysis Plan Appendix, Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC). Prepared for the Washington State Department of Ecology by PTI Environmental Services, Bellevue, WA. Ecology publication No. 03-09-043. April 2003.

Nautilus. 2007. Marine Sediment Toxicity Testing. 2007 PSR Monitoring Elliot Bay, Seattle Washington. Prepared for SAIC, Bothell, WA. Prepared by Nautilus Environmental, LLC. January 16, 2008.

PSEP. 1995. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Interim Final report. Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Science Applications International Corporation (SAIC). 2006. 2006 Long Term Monitoring, Pacific Sound Resources Superfund Site, Seattle, Washington; Monitoring Report Final. Prepared for U.S. Army Corps of Engineers, Seattle District, Seattle, WA. Prepared by Science Applications International Corporation, Bothell, WA. November 17, 2006.

SAIC. 2007. 2007 Long Term Monitoring, Pacific Sound Resources Superfund Site, Seattle, Washington; Quality Assurance Project Plan. Prepared for U.S. Army Corps of Engineers, Seattle District, Seattle, WA. Prepared by Science Applications International Corporation, Bothell, WA. August 1, 2007.

U.S. Army Corps of Engineers (USACE). 2002. Engineering and Design Hydrographic Surveying. Manual No. 1110-2-1003. January 2002

USACE. 2004. Final Operation, Maintenance, and Monitoring Plan, Pacific Sound Resources Superfund Site, Marine Sediment Unit. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA. Prepared by U.S. Army Corps of Engineers, Seattle District, in coordination with URS Group, Seattle, WA. September 2004.

USACE. 2005. Draft Remedial Action Report, Pacific Sound Resources Superfund Site, Marine Sediments Unit, Seattle, Washington. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA. Prepared by U.S. Army Corps of Engineers, Seattle District, in coordination with URS Group, Seattle, WA. September 9, 2005.

USACE. 2007. Statement of Work, Contract W912DW-05-D-1003, Task Order No. 8, Long Term Monitoring Pacific Sound Resources Superfund Site, Seattle, WA. Prepared by U.S. Army Corps of Engineers, Seattle District. May 01, 2007.

USEPA. 1998. Remedial Investigation Report, Pacific Sound Resources, Marine Sediments Unit, Seattle, WA. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA. Prepared by Roy F. Weston, Inc., Seattle, WA. January 1998.

USEPA. 1999. Pacific Sound Resources (PSR) Superfund Site, Seattle, Washington, Record of Decision. September 30, 1999.

APPENDIX A

2007 LONG TERM MONITORING PSR FIELD REPORT

Appendix B

2007 Long Term Monitoring PSR Chemical Data Final Report

Appendix C

Analytical Laboratory Report

(Included on CD)

APPENDIX D

BIOLOGICAL LABORATORY REPORT

(INCLUDED ON CD)

Appendix E

Bathymetric Survey Information

APPENDIX F

BEACH SURVEY IMAGES

Appendix G

Subsurface Core Images